Chapter 3
Vegetation Communities

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3.0 VEGETATION COMMUNITIES

The vegetation community monitoring program was designed to provide a lagoon-wide assessment of vegetation communities, identify the presence and distribution of various habitat types and species, and compare post-restoration conditions with those that existed prior to tidal influence being returned to the lagoon.

3.1 METHODS

3.1.1 Aerial Photography and Habitat Mapping

Color infrared (CIR) aerial photography was used to facilitate vegetation mapping and long-term vegetation trend analyses. The CIR photography was acquired during flights conducted in late summer or early fall of 1997, 1998, 1999, 2000, 2001, 2003, 2005, and 2006. All flights were timed to coincide with low tides (typically +0.2 to -0.3 foot mean lower low water [MLLW] La Jolla ocean datum) to maximize exposed intertidal habitat. As tidal conditions continued to deteriorate over the years, the actual water elevation at the time the images were taken likely deviated considerably from the elevation targeted using oceanic tidal predictions. Aerial photographs were collected along flight lines at an altitude of 5,000 feet mean sea level (MSL), and photos were processed into digital orthophotos with a resolution of one foot per pixel. One additional high altitude shot was taken for reference at 15,000 feet MSL in 1997, 1998, 1999, 2001, and 2006.

Prior to flights, survey crews set ground control points to serve as the basis for multi-year photogrammetric products. Photography was aerial-triangulated using 11 horizontal and vertical ground control points and 5 additional vertical-only control points. The ground control points were collected on North American Datum 1983 (NAD83) in California State Plane coordinates Zone 6 and National Geodetic Vertical Datum 1929 (NGVD29). The aerial-triangulation, surface data, and images were used to produce digital orthophotos using OrthoView© software. The orthophotos were processed as 24-bit, 3-band color TIFF images. The orthophoto set was tiled into six orthophoto images, each covering approximately 4,550 feet by 2,050 feet.

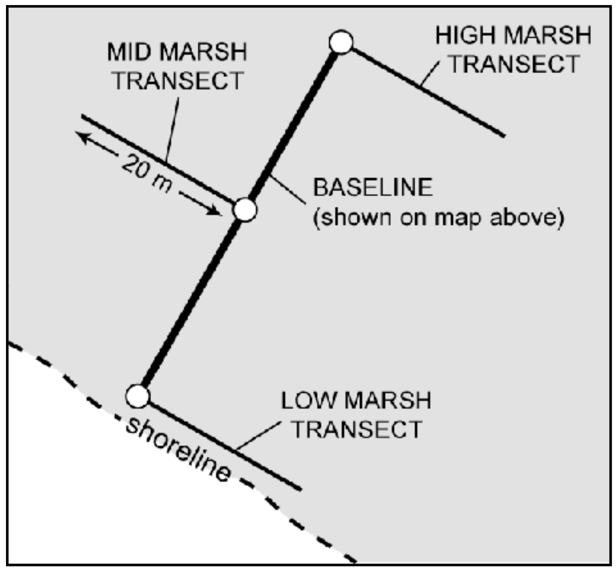
The geo-rectified orthophoto images were processed for maximum accentuation of wetland vegetation and sub-tidal water penetration for use in identifying the boundaries of 19 habitat types. The vegetated and unvegetated habitat features were defined by physical characteristics and/or dominant plant species composition. A preliminary vegetation coverage map was generated by digitizing habitats over the orthophoto background image using ArcView® Geographical Information Systems (GIS) software. The preliminary vegetation coverage was plotted at a 1:2,400 scale, then adjusted through field investigations and aerial photo interpretation. Lagoon-wide ground-truthing was conducted in years 1997 and 1998. In subsequent years, the vegetation maps were ground-truthed to a more limited degree by visiting points identified at the boundaries of dynamic habitats, such as expanding cordgrass (*Spartina foliosa*) and coastal salt marsh. The more static and previously proofed habitats, such as coastal sage scrub, were delineated through inspection of the current and past imagery.

Following ground-truthing and comparison on maps between years, all adjustments were incorporated into the GIS database, and a final set of vegetation maps was generated. Acreage tables of each of the studied habitats were determined for each year from the GIS database. For consistency in vegetation mapping, the tidal waterline at the time of photography was utilized to determine the acreages of shallow water and mudflat habitats (see limitations below).

3.1.2 Salt Marsh Transect Monitoring

Eight permanent vegetation sampling sites were established during pre- and post-construction monitoring surveys (Wetlands Research Associates 1994, 1997) (Figure 3-1). The same sites and methodology were utilized during annual post-restoration vegetation monitoring conducted in early fall of 1997, 1998, 1999, 2001, and 2006. At each site, a baseline transect was established perpendicular to the shoreline. Points were established along each baseline within each marsh zone (high, middle, and low). At each point, a 20-meter fiberglass measuring tape was extended away from the baseline, parallel to the shoreline. The coordinates for the transects are listed in Appendix A3-1. A photograph of the site was taken each year to further document changes over time.

At each vegetation transect, the percent cover of plant species and bare ground/open water was determined. Cover of individual plant species was recorded for each meter along the 20-meter transect, and percent cover of plant species and bare ground/open water was determined using the line-intercept method (PERL 1990). Plants and bare ground/open water were recorded only if a part of the plant or bare space fell underneath the vertical plane of the fiberglass measuring tape. The minimum unit of intercept recorded was one decimeter. Total percent cover along a transect could exceed 100% due to overlapping plant species.



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Vegetation transects and sampling locations

Figure 3-1

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Soil and/or water salinity was also determined along each sampling transect. Soil salinity was estimated using a 10-centimeter soil core. Interstitial soil water was filtered from the soil core using a syringe containing two No. 1 filter papers. Filtered water was placed onto a refractometer and the salinity recorded to the nearest part per thousand (ppt). If a transect occurred over open water, water salinity was measured instead. A 200-milliliter sediment sample was randomly collected along each transect, transported to the laboratory, and analyzed for grain size distribution and total organic carbon (TOC).

3.1.3 Pre-Restoration Data Review

Previous aerial photographs taken in 1988 were analyzed as part of the Batiquitos Lagoon Enhancement Project Final EIR/EIS and included field studies conducted in June 1988 (City of Carlsbad and U.S. Army Corps of Engineers 1990). The resulting vegetation map divided the lagoon vegetation into five wetland habitat categories. This limited classification system prevented direct comparisons with the current vegetation mapping but did allow for limited assessments of pre- and post-restoration conditions.

Vegetation transect monitoring was conducted by Wetlands Research Associates (WRA) in 1994 and 1996 (WRA 1994, 1997) before and after "construction" of the restoration project. The results of those surveys were reviewed and summarized for comparison to the post-restoration data collected from 1997 to 2006.

3.1.4 Study Program Limitations

No accurate tidal gauge was installed at Batiquitos Lagoon to assist with documenting actual tide stages. As discussed above, a tide level of approximately +0.2 to -0.3 foot MLLW was targeted for the collection of aerial imagery each year to allow comparison of habitat availability between years. Collecting the aerial imagery consistently at this tide stage was not possible due to the inability to accurately determine the true tidal elevations within the lagoon, differing elevations within each lagoon basin, and an inability of the lagoon to drain out to that elevation (see Chapter 1). By year 10 (2006), it is estimated that the east basin of the lagoon did not fall to below a tide level of +0.9 foot MLLW and only reached that level at extreme low tides. Therefore, acreages of open water, mudflat, intertidal sand beaches and shoals, and other intertidal habitats were not consistently quantified at the same tide elevation. This means that estimates of mudflat, intertidal sand beaches and shoals, and other intertidal habitats are likely underestimated and open water overestimated in later years. For standardization of water area, realized tidal elevation-based water surfaces are reported elsewhere in this document for as-built (1996) conditions and 2008, where adequate tidal range data were available (see Chapter 2)

The location of the vegetation transects monitored in this program were established in 1994 as part of the pre-construction monitoring effort completed by WRA (1994). The locations of low marsh elevation transects were established in open water areas that were predicted to be able to support low marsh vegetation once the construction of the lagoon was complete (WRA 1994). However, several of these transects, such as at Sites 2, 4, 5, and 6, remained continually submerged or subject to changing physical conditions that prevented colonization by coastal salt marsh vegetation. The low marsh transect at Site 3 was eliminated in 1997 due to its loss resulting from construction dredging activities. All other low marsh transects were surveyed, although only Site 1 supported vascular vegetation by the end of the monitoring program.

The lack of vegetation developing as predicted was due to the incomplete low tide drainage of the lagoon as a result of tidal muting and lag. Although the lower portion of the marsh was anticipated to be subject to the greatest changes resulting from lagoon hydraulic developments and changes in soil chemistry, the lack of low marsh data limited the ability to complete meaningful change analyses within this vegetation zone. Low marsh was separately examined, however, as it pertains to cordgrass development since this species was introduced as a pilot transplant effort (see Chapter 4).

In some years, additional imagery was available that offered superior penetration into the water, reduced glare, or a better image overall. In such cases, this alternative image has been presented and is noted where appropriate.

3.2 RESULTS

3.2.1 Aerial Photography and Habitat Mapping

Figures 3-2a, b, and c present the color aerial imagery collected over the 10-year monitoring period. The imagery provides an overview of the changes in the surrounding urban development and physical features of the lagoon, as well as sediment accretion and the development of various habitats. Notable changes year to year include additional housing built to the north of the central and east basins, the portion of the central basin flood shoal removed in the 2003 dredging, the developing morphology of tidal channels, the infilling of the subtidal area surrounding the island nesting site (E-3) at the east end of the lagoon, the expansion of eelgrass (*Zostera marina*) over time, and the development of other vegetation communities as described below.

The distribution of the 19 mapped habitat types is quantified in Table 3-1. As discussed above, note that the waterline in the photo was used as the boundary between mudflat and open water. The habitat maps for each survey year are presented in Figures 3-3a, b, c, and d.

Table 3-1. Habitat acreages at Batiquitos Lagoon (1997-2006).

Habitat Type	1997	1998	1999	2000	2001	2003	2005	2006
Open water (including eelgrass)	246.0	233.9	216.9	242.7	215.5	242.0	234.3	233.8
Intertidal sand beach/shoal	4.8	6.9	13.4	9.8	9.1	11.3	13.3	15.9
Intertidal mudflat	133.2	139.9	127.4	97.6	120.2	49.6	57.0	44.7
Nesting site	37.0	36.2	37.0	34.9	37.7	36.2	35.2	32.7
Salt panne	13.0	11.4	12.4	9.7	7.7	17.0	15.2	16.1
Eelgrass bed	0.2	0.7	4.5	53.4	39.1	104.0	70.8	79.3
So. coastal salt marsh (cordgrass dominated)	0.0	0.4	0.3	1.0	2.0	24.6	47.6	52.9
So. coastal salt marsh (pickleweed dominated)	65.6	85.0	102.7	125.1	135.9	144.9	112.7	118.2
Goldenbush saline meadow	5.6	7.1	11.2	9.4	7.0	8.0	8.2	6.6
Brackish marsh	50.0	38.9	29.6	18.9	13.5	7.5	13.8	14.3
Freshwater marsh	21.7	22.7	27.8	33.2	32.0	39.3	34.5	40.2
Southern willow scrub	11.6	9.8	11.2	8.9	14.9	14.5	14.1	14.1
Tamarisk scrub	0.3	0.1	0.5	0.2	0.4	1.0	0.4	0.4
Diegan coastal sage scrub	27.2	22.8	17.8	20.9	15.8	27.5	30.6	29.1
Disturbed upland	17.8	14.1	22.5	19.3	19.3	14.0	16.4	14.7
Non-native grassland	2.9	3.3	2.4	1.2	3.1	0.3	0.6	0.0
Eucalyptus woodland	5.3	4.6	5.4	6.7	5.8	5.4	5.3	5.6
Decaying vegetation	0.0	0.3	0.6	0.0	0.0	0.0	0.0	0.0
Trail/developed land	6.5	11.5	10.3	9.7	9.2	6.3	10.1	9.8

Annual aerial images of Batiquitos Lagoon during construction (1996) and post-construction (1997 and 1998)

Figure 3-2a

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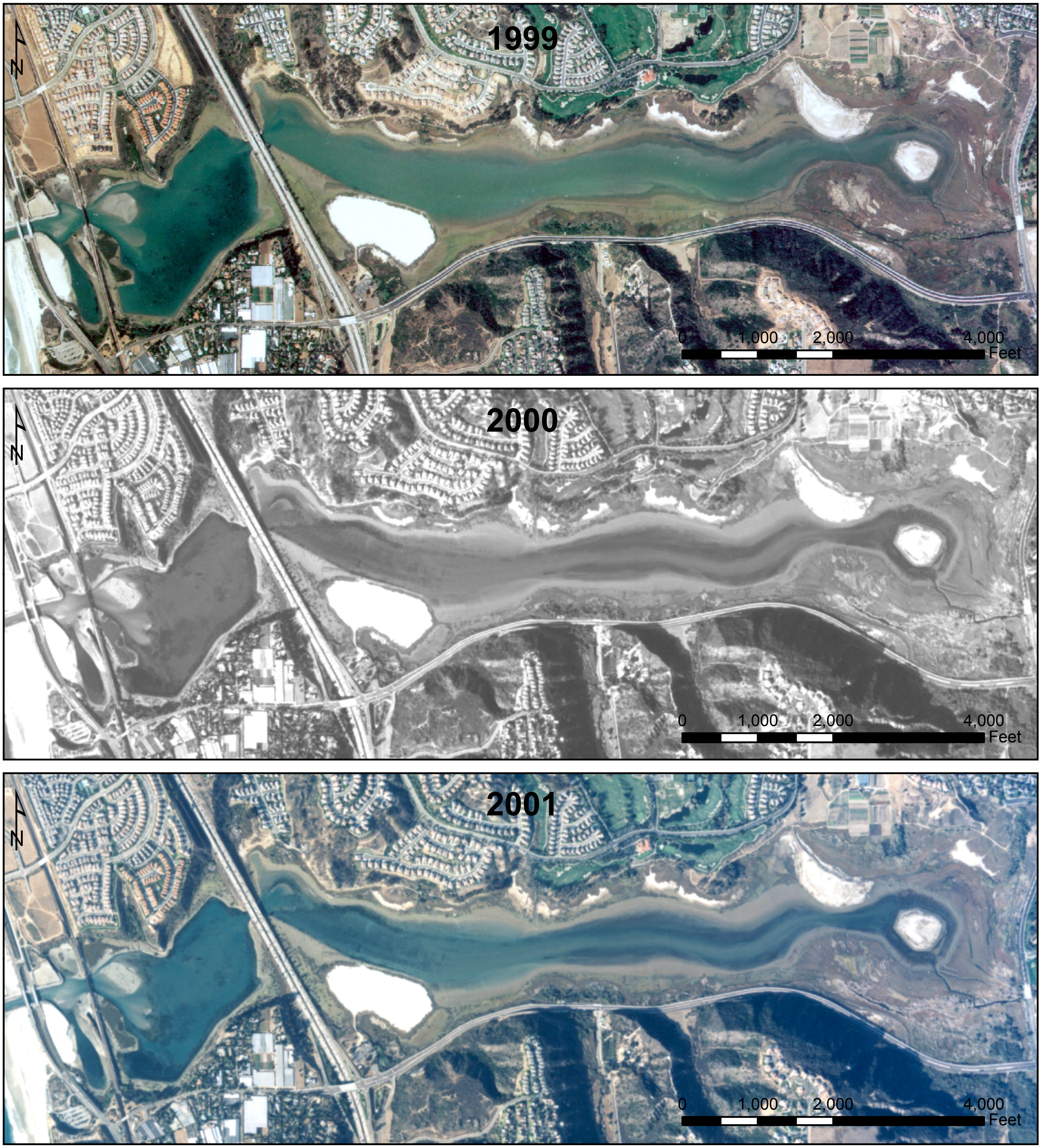

Annual aerial images of Batiquitos Lagoon
(1999, 2000, & 2001)

Figure 3-2b

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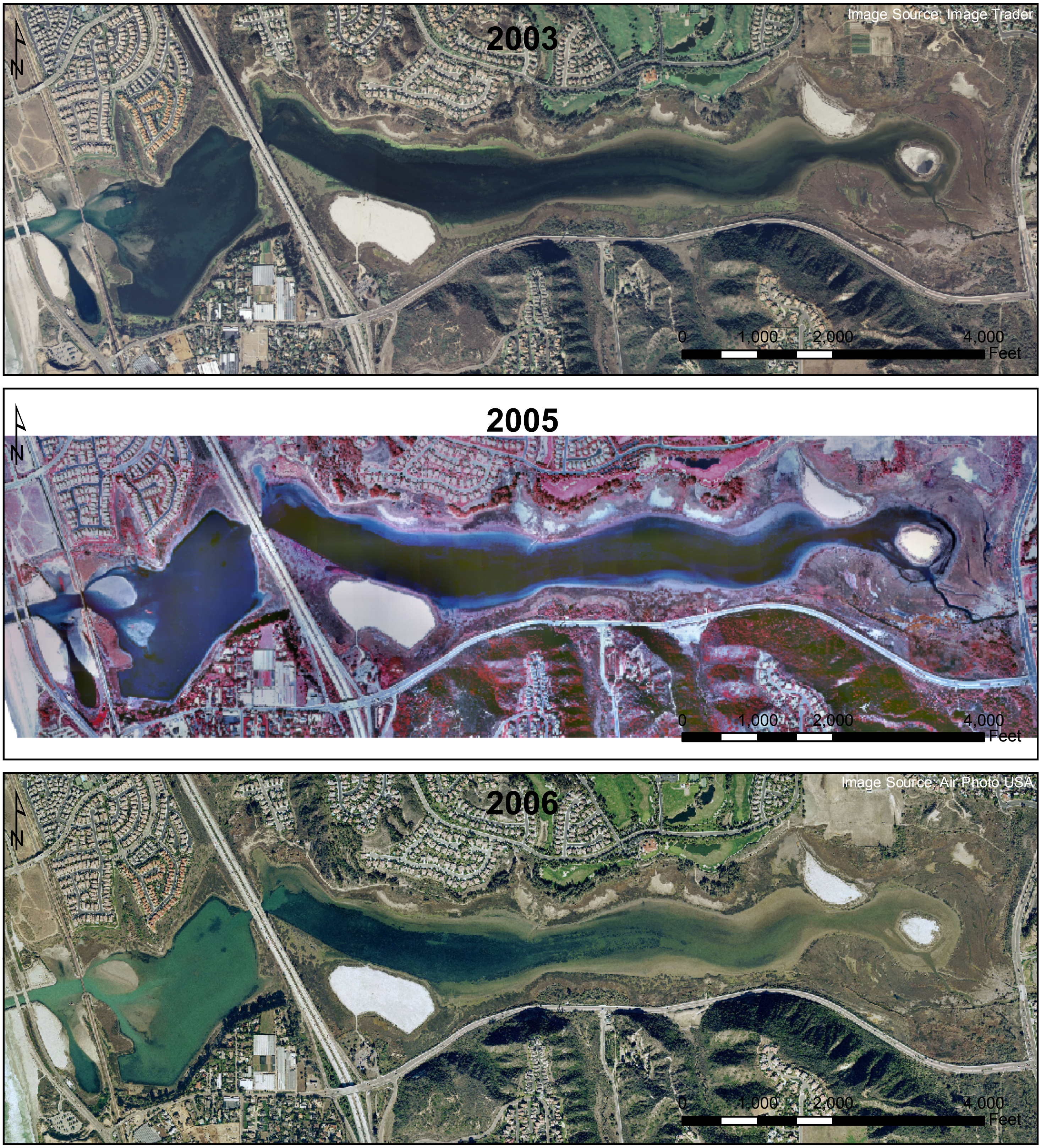

Annual aerial images of Batiquitos Lagoon (2003, 2005, & 2006)

Figure 3-2c

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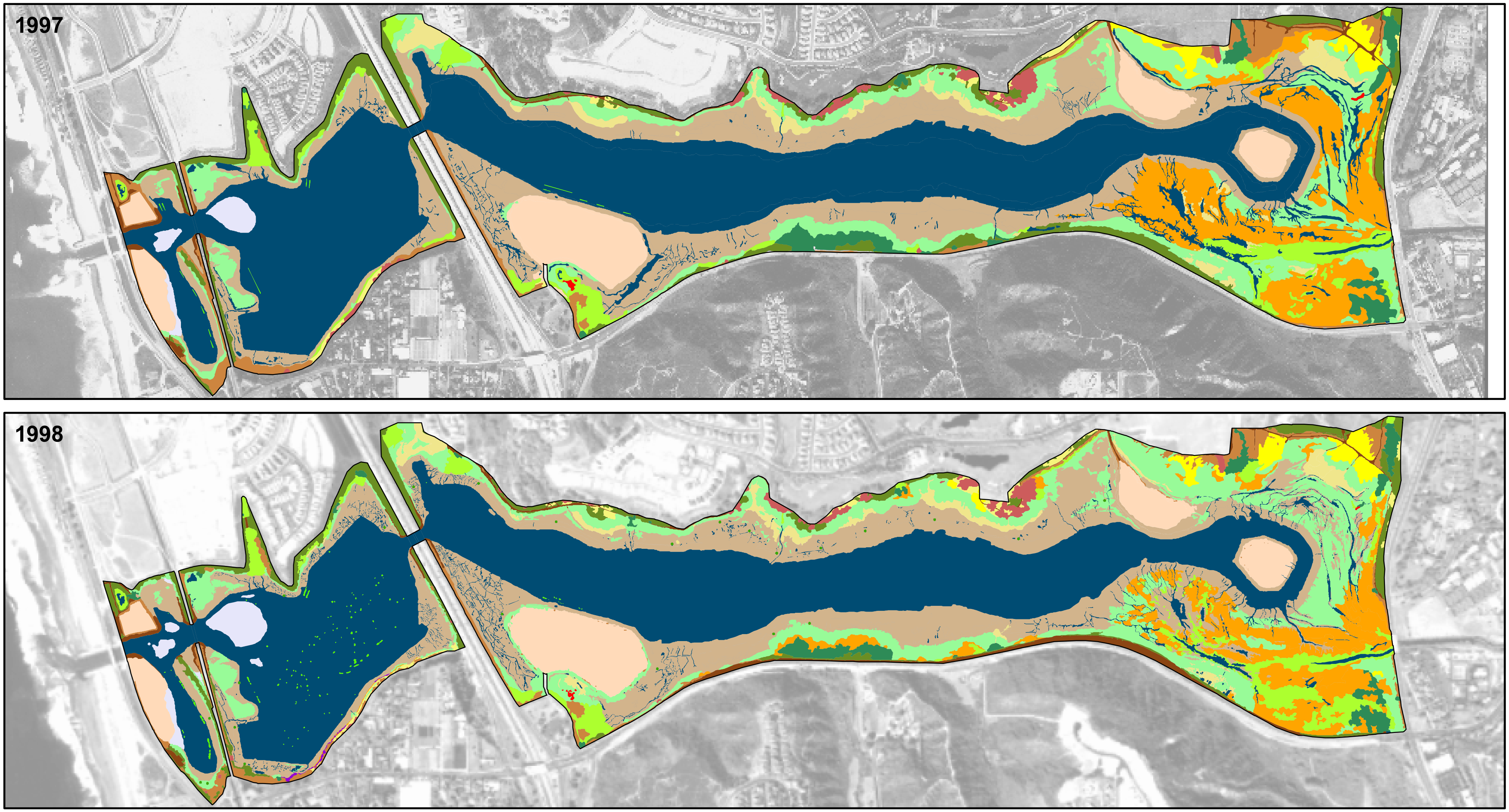

Open Water	Salt Panne	Goldenbush Saline Meadow	Tamarisk Scrub	Eucalyptus Woodland
Intertidal Sand Beach/Shoal	Eelgrass Bed	Brackish Marsh	Diegan Coastal Sage Scrub	Decaying Vegetation
Intertidal Mudflat	Southern Coastal Salt Marsh (Cordgrass dominated)	Freshwater Marsh	Disturbed Upland	Trail/Developed Land
Nesting Site	Southern Coastal Salt Marsh (Pickleweed dominated)	Southern Willow Scrub	Non-Native Grassland	

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Batiquitos Lagoon habitats (1997 and 1998)

Figure 3-3a

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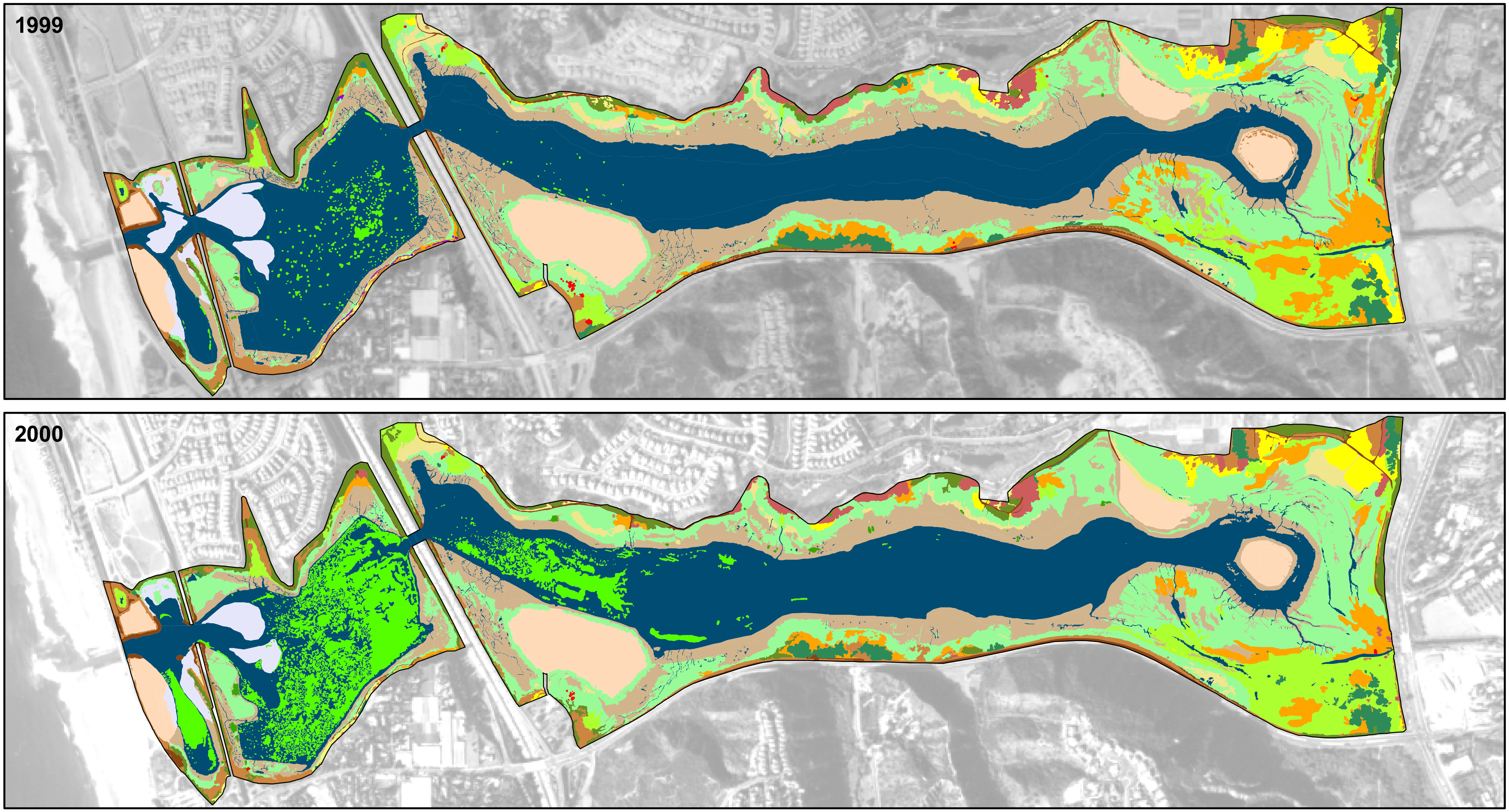

Open Water
Intertidal Sand Beach/Shoal
Intertidal Mudflat
Nesting Site
Salt Panne
Eelgrass Bed
Southern Coastal Salt Marsh (Cordgrass dominated)
Southern Coastal Salt Marsh (Pickleweed dominated)
Goldenbush Saline Meadow
Brackish Marsh
Freshwater Marsh
Southern Willow Scrub
Tamarisk Scrub
Diegan Coastal Sage Scrub
Disturbed Upland
Non-Native Grassland
Eucalyptus Woodland
Decaying Vegetation
Trail/Developed Land

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Batiquitos Lagoon habitats (1999 and 2000)

Figure 3-3b

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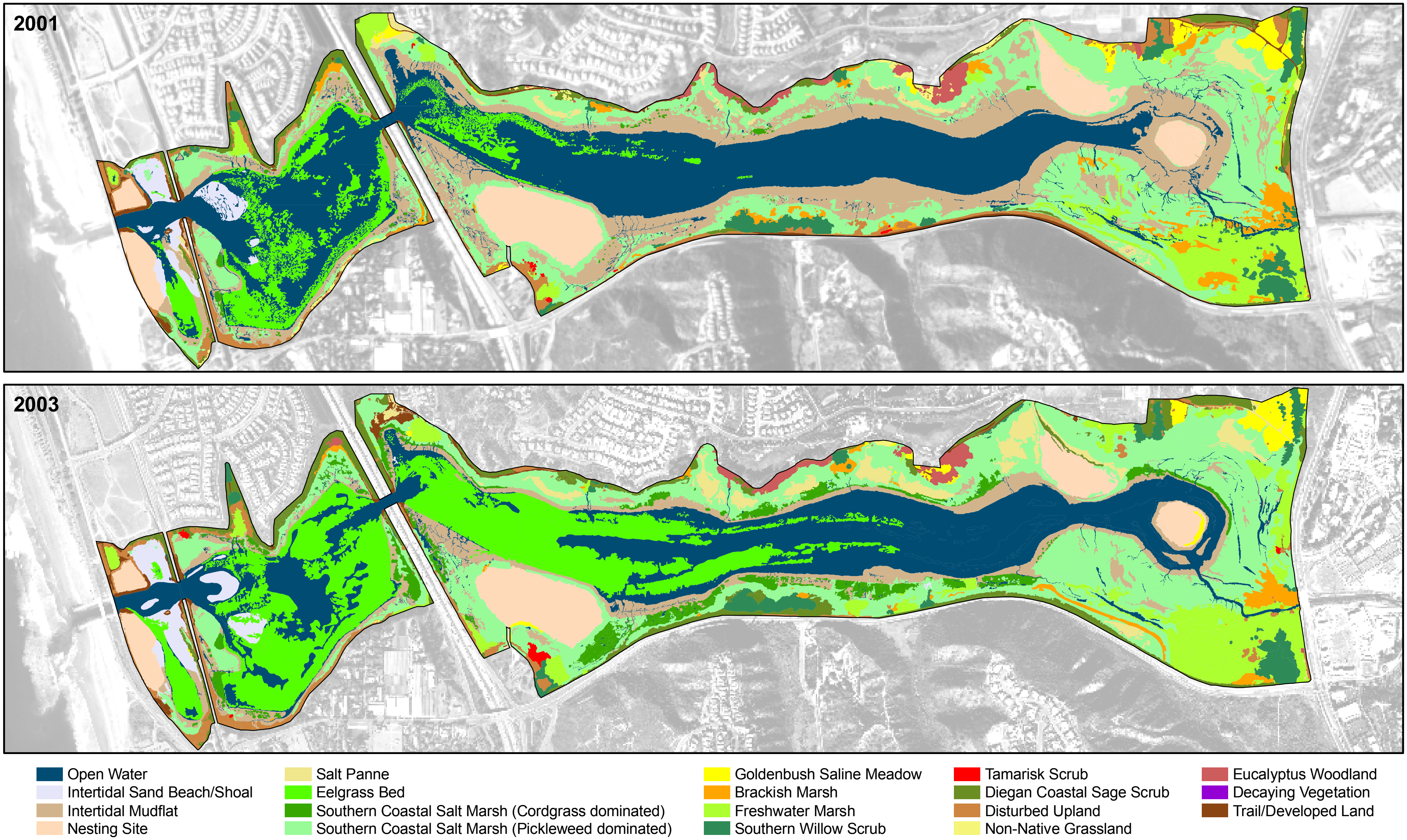

Batiquitos Lagoon habitats (2001 and 2003)

Figure 3-3c

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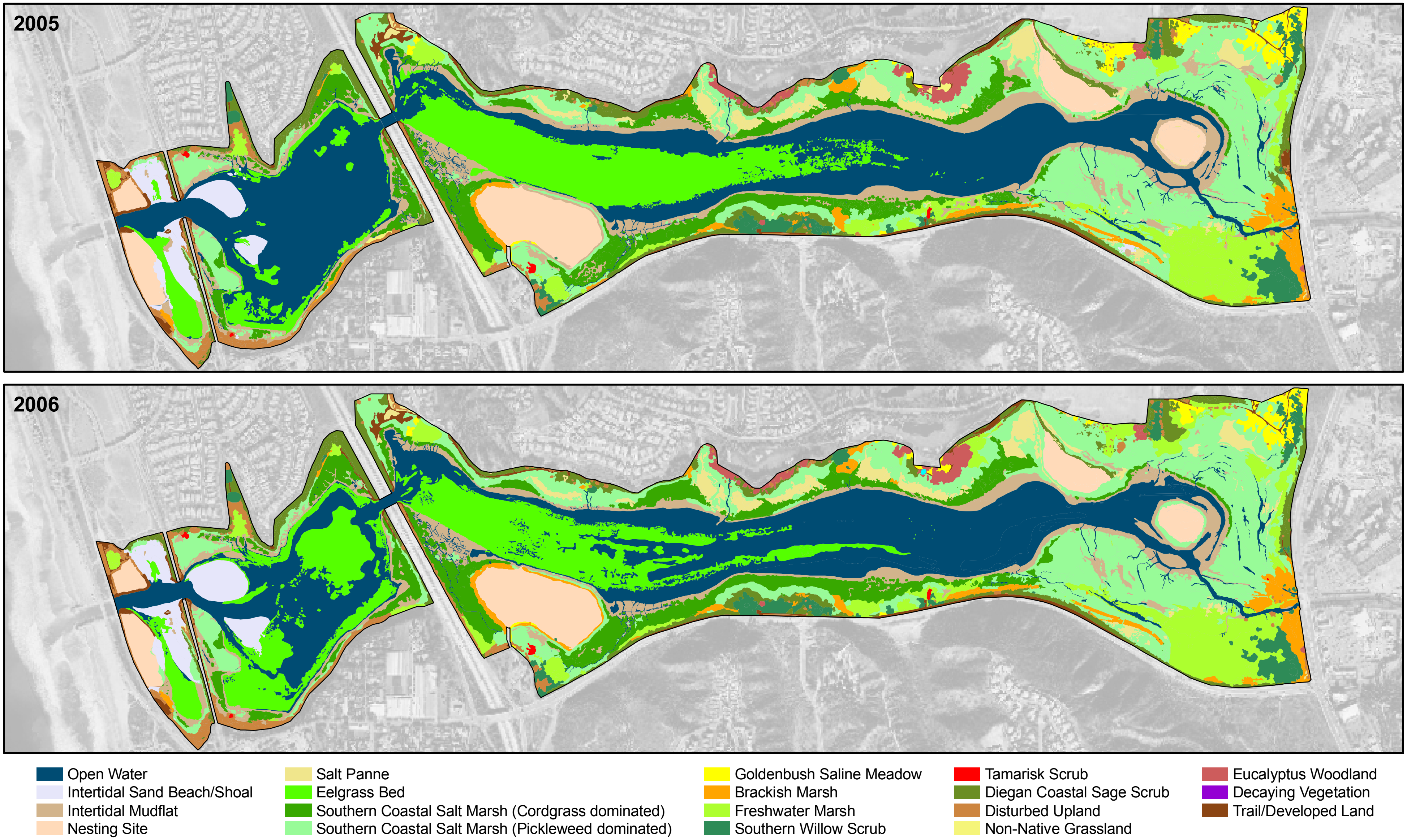

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Batiquitos Lagoon habitats (2005 and 2006)

Figure 3-3d

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The study area is dominated by subtidal and intertidal habitats that are vegetated by limited numbers of vascular plants and algal species. Surrounding this subtidal and low intertidal zone, are saline and brackish marshlands. At elevations above these marshlands, are limited riparian woodlands located at sources of freshwater inflows and, in more xeric areas, a wide range of upland habitats ranging from Diegan coastal sage scrub to Eucalyptus woodlands. While not all of the described habitat elements function independently of other habitats, they were mapped separately to aid in tracking changes in the lagoon environment over time. The developing morphology of intertidal areas and the response of surrounding vegetation provided important insight into marshland formation processes. Therefore, specific attention was given to mapping fine details in these areas. Information gathered from this system will prove useful in designing other restoration projects and predicting the rate of development in restored marshlands. Specific habitats mapped in Figures 3-3a-d are described below, followed by a comparison of pre- and post-restoration vegetation conditions.

<u>Open Water</u>

Open water within Batiquitos Lagoon consists nearly entirely of marine waters that are seasonally influenced by freshwater flows, particularly into the eastern basin. Water quality readings taken during other biological monitoring elements found lagoon waters were fully tidal, and water salinities ranged from a low of 17.7 ppt in April 1998, near San Marcos Creek in the east basin, to a high of 35.3 ppt in the west basin, with a mean of 32.7 ppt throughout the lagoon (see Chapter 5). Open water habitat was considered to include the waters of the west, central, and east basins extending from the visible water line down to the deepest parts of the lagoon. As described above, tidal muting in the lagoon prevented delineation of open water at the 0 foot MLLW elevation from the photographs as originally planned. Therefore, the open water acreages should not be used as an estimate of available habitat below mean lower low water. See Chapter 2 for a detailed discussion of the open water habitat availability.

Also mapped as open water are intertidal channels. The aerial photographs show the development of channels and larger tidal channels that drain from mudflats and salt marsh areas (Figures 3-2a, b, and c). The initial configuration of the channels was angular as many of them followed the dredge cut scars and propeller scarring left on the tidal flats by construction vessels. Over time, the channels consolidated. Major channels became established and are now the primary drainage locations on mudflats, while smaller channels have begun to fill in and return to mudflat or to coastal salt marsh habitat. In the far east basin, the larger channels are primarily associated with the terminus of San Marcos Creek. After the opening of the lagoon mouth, significant erosion occurred in this area, creating an approximately 5 to 10-foot wide channel that entered the lagoon along the south side of the E-3 nesting site. The extensive rainfall in late 1997 and early 1998 brought deposition of materials downstream along San Marcos Creek creating a flatter, shallower marsh plain at the mouth of the channel that remained through 2006 (Figure 3-2c).

<u>Intertidal Mudflat</u>

A substantial portion of the eastern basin, and a smaller portion of the central and western basins, supports unvegetated intertidal mudflats. The microtopography and sediment consistency of the mudflats varied extensively as a result of the restoration construction activities. The sweep of the dredge cutter-head over the lagoon bottom left a lingering pattern of concentric arcs forming an irregular surface of ridges and valleys with a vertical relief of roughly 0.3 meter. As the site weathered over time, this relief was reduced as fine sediments filled the depressions and the sharp ridges eroded away to a more rounded form. However, the dredge ridges still remain in several portions of the lagoon and are visible on some of the east basin mudflats in particular (Figure 2-8). Overall, the mudflats have become more uniform in appearance but retain a high variability with respect to sediment density between and on the ridges (see Chapter 2).

Included within the mudflat habitat category are algal beds, which were seasonally and sporadically abundant in areas where broad expanses of mudflats occur and tidal scouring was not prohibitive. Typically, these algal beds were most developed on nearly level terrain within the eastern basin. The dominant algae included a mix of *Ulva* and *Enteromorpha* species. Diatom films also covered extensive portions of the intertidal mudflats and shallow lagoon bottom at times. These algal beds were typified by seasonal and interannual patchiness. The algal patches were variable in the aerial imagery depending on the recent fluvial input and tidal history, as well as wind conditions at the time of the image collection. Due to this variability and highly transitory nature, algal beds have not been called out as a separate habitat as they were in earlier annual reports.

The amount of mudflat mapped declined over the 10-year monitoring period for three reasons. First, for the purposes of acreage calculation, the waterline visible in the aerial imagery was used to define the interface between mudflats and open water. As the tidal muting became more pronounced over time, the waterline at the low tide condition in the photo moved upward, moving the waterside boundary of mudflat upward as well. Secondly, the upper edge of the mudflat shifted to lower elevations as southern coastal salt marsh vegetation expanded downward across the mudflat. In the first few years post-restoration, the colonization was by pickleweed (*Sarcocornia pacifica*), then in later years by cordgrass (Figures 3-2a-d). Finally, there was some loss of mudflat in the west basin due to erosion by incoming wave energy and burial by incoming littoral sands and in the central basin due to scouring tidal flows.

Expansion of salt marsh vegetation accounted for the majority of the approximately 65% reduction in mudflat habitat from 1997 to 2006. See Chapter 2 for a detailed discussion of the physical processes underpinning habitat transitions within the lagoon.

Nesting Site

Five nesting sites were built of mud and capped with sand excavated from the central basin to encourage nesting by the California least tern (*Sternula antillarum browni*) and western snowy plover (*Charadrius alexandrinus nivosus*). The approximately 37.0 acres of sand nesting sites was reduced over time as vegetation encroached on the five sites (Figure 3-2a-d). Nesting sites W-1 and E-3 became vegetated by weedy species, while E-1 and E-2 became encircled by coastal salt marsh and brackish marsh vegetation.

Nesting site W-2 was severely eroded along its eastern flank, and portions of this site were converted to intertidal sand beach. By 2006, available nesting site area had been reduced to 32.7 acres as a result of conversion to other coastal wetland and intertidal habitats. In most instances, this conversion was anticipated to occur based on the early mapped extent of nesting sites into the intertidal zone of the lagoon.

Intertidal Sand Beaches/Shoal

As discussed in Chapter 2, flood shoals of littoral beach sand formed in the west and central basins. The portion of these shoals that were exposed at the low tide captured in the photo was mapped as intertidal sand shoals. The acreage of this habitat does not reflect the full extent of the shoals, which extend down to subtidal elevations. Intertidal sand beaches were formed through the weathering of fine sands off of the nesting sites onto the surrounding shoreline; winnowing of fines out of sandy sediments, thus resulting in a sandy remainder beach; or as a result of sand migration into the lagoon followed by accretion in areas where tidal current energies were reduced. This habitat was most abundant in the west basin, where mudflat was replaced by sands pushed up onto the northern and eastern shoreline of the basin in years 1-3. All sandy areas were comprised of predominantly unstable sediments of low organic content. Over the course of the monitoring period, this habitat increased in area from 4.8 to 15.9 acres, attributable primarily to the expansion of the central basin flood shoal and the sand beaches in the west basin.

Salt Panne

Seasonally inundated salt panne comprised most of the lagoon environment during pre-restoration conditions. Under post-restoration conditions, several areas of unvegetated salt panne have persisted on the north, south, and east shore of the east basin where topographic depressions at high elevations capture spring tide waters or seasonal rainfall and storm discharges. Salt panne within the lagoon was formed before the lagoon mouth was breached and has remained hypersaline and inhospitable to most plants due to persisting sediment chemistry conditions. Prolonged inundation and high evaporation rates result in low sediment oxidation-reduction potential (ORP) and high salinities in these environments. Salt panne at the eastern end of the east basin has persisted where incoming marine waters are trapped during the highest spring tides and later evaporate, leaving hypersaline soils and a surface veneer of salt. The salt panne behind nesting site E-2 remained unvegetated as well, with the evaporation of trapped runoff and rainwater continuing to keep soil salinities high. The higher salinity soils surrounding the salt panne habitat have allowed the persistence of coastal salt marsh (particularly pickleweed) at higher than usual tidal elevations due to minimal competition from terrestrial vegetation, which is mostly incapable of tolerating the high salt levels. The amount of salt panne varied annually based on the ability of coastal salt marsh vegetation to encroach on the unvegetated panne. Over the coming decades, it is anticipated that this habitat will diminish as basins sediment in and channels develop to provide drainage of the basins to open lagoon environments.

Eelgrass Beds

Approximately 0.25 acre of eelgrass was transplanted into the three lagoon basins by Merkel & Associates (M&A) in 1997 and 1998. These transplants were completed with the expectation that they would expand to other areas suitable for eelgrass growth. The transplant and resulting expansion are detailed in Chapter 4. The original transplant expanded through all three basins. Table 3-1 presents the maximum extent occurring in 2003 with 104 acres, dropping in 2005 to 71 acres. However, mapping conducted outside of the present monitoring program in early 2005 found an extent of 120 acres (see Chapter 4). Lagoon-wide, eelgrass grew within a tidal range of approximately –5.5 feet to +1.0 foot MLLW, based on the 2008 bathymetry data presented in Chapter 2.

Southern Coastal Salt Marsh

Most intertidal salt marshes of southern California are viewed as having three distinct zones: a low marsh that is inundated by nearly every high tide and is dominated by cordgrass; a middle marsh, inundated by higher high tides and dominated by pickleweed; and a high marsh, inundated only by high spring tides and dominated by one or more species including pickleweed, salt grass (*Distichlis spicata*), and alkali heath (*Frankenia salina*). At Batiquitos Lagoon, a recognizable zonation between the high and middle marsh zones had not become clearly established by year 10. The low and middle marsh zones were distinct, with cordgrass occupying the low marsh exclusively and *S. pacifica* dominating the middle marsh. On the north shore of the east basin, these zones were often separated by salt panne; whereas on the south shore, the cordgrass abutted *S. pacifica* directly (Figures 3-3d).

Due to interest in cordgrass as a distinct element of southern coastal salt marsh, a pilot restoration effort was undertaken to introduce this species into the lagoon and monitor its establishment. Areas dominated by cordgrass were mapped separately (Table 3-1). The introduction and expansion of cordgrass is detailed in Chapter 4. Approximately 0.4 acre was originally transplanted in 1998 at 20 locations throughout the lagoon. It slowly expanded vegetatively and by seed for the first four years and then expanded rapidly in subsequent years. By 2003, cordgrass had expanded to 24.6 acres and doubled to 52.9 acres by 2006. It colonized previously unvegetated mudflat, extending upslope to the pickleweed marsh and downslope to its inundation frequency limit. In 2006, cordgrass ranged between approximately +1.8 and +6.0 feet MLLW, with a mean elevation of approximately +3.7 feet MLLW (based on 2008 bathymetric conditions).

The high coastal salt marsh was moderately diverse (eight species total in monitored transects) and dominated by *S. pacifica*, alkali heath, and salty Susan (*Jaumea carnosa*). The middle marsh was slightly less diverse and dominated by *S. pacifica* and alkali heath. Other pickleweed species, *Salicornia bigelovii* and *Arthrocnemum subterminale*, were not observed in any monitored transects or other field studies, but may be present at the lagoon in limited areas.

Post-restoration, the pickleweed dominated coastal salt marsh expanded into freshwater and brackish marsh in the east basin that had been forced to retreat due to higher soil salinities resulting from tidal inundation. The nearly monotypic salt marsh then expanded rapidly onto the mudflats throughout the lagoon, particularly in the east basin (Figures 3-2a-d). Pickleweed (*S. pacifica*) recruits colonized the newly bare areas in 1997; and by 1998, sizeable stands of young pickleweed plants were established on the mudflat. From 1999 through 2001, pickleweed continued to expand over unvegetated mudflat throughout the lagoon. By 2003, the amount of pickleweed dominated coastal salt marsh had more than doubled from 66 to 145 acres, as open mudflats continued to be colonized (Table 3-1). The rapid expansion of cordgrass up from lower elevations then displaced roughly 30 acres of pickleweed by years 9 (2005) and 10 (1996). This transition can be most clearly seen in Figures 3-2c and 3-2d, on the south shore of the east basin, behind nesting site E-1.

An analysis made prior to the restoration by Ogden Environmental and Energy Services (1994) estimated the restoration project impacts to coastal salt marsh would be approximately 11.5 acres. Project permits specified that impacts to coastal salt marsh were to be mitigated at a 4:1

ratio, to be met by the end of the 10-year monitoring period. The Ogden (1994) document reported the pre-restoration salt marsh within the system to be 123 acres. With the impact mitigation, the post-restoration system was required to support a total of 157.5 acres of coastal salt marsh in accordance with permit conditions. The mitigation acreage requirement was met by year 7 (2003) of the post-restoration monitoring period, when the lagoon supported 169.5 acres of coastal salt marsh habitat. Coastal salt marsh coverage remained stable in the following years, with over 171 acres of marsh being present in year 10 (2006). As a result, Batiquitos Lagoon has met and exceeded the numeric marsh replacement requirements established in project permits.

It is important to note the presence of a small infestation of the non-native invasive grass *Phragmites australis* in the coastal salt marsh in the northwest corner of the east basin. It was detected at Batiquitos Lagoon in October 2002, at which time the population was small and comprised of approximately 100 stalks (K. Palenscar pers. comm.). The origin of its introduction into the lagoon is unknown. Research has shown that there is a native and introduced genotype occurring in the U.S. The introduced genotype is known to be highly invasive. Mr. John Ekhoff, a botanist from CDFG, sent samples from the Batiquitos population to the San Diego Natural History Museum herbarium and to UC Davis for analysis. The population at Batiquitos Lagoon was reportedly determined to be the invasive variety, and the patch was treated with herbicide by CDFG. In subsequent years, it persisted but spread little. In Spring 2006, the patch was mapped by M&A and found to cover approximately 961 ft^2.

<u>Goldenbush Saline Meadow</u>

Within the northern periphery of the eastern basin, an ecotonal mix of upland and wetland, saline-tolerant plants exists, dominated by coast goldenbush (*Isocoma menziesii*) and wild radish (*Raphanus sativus*), along with Eurasian grasses (*Bromus rubens* and *Vulpia myuros*), cocklebur (*Xanthium strumarium*), salt marsh fleabane *(Pluchea odorata*), and some pickleweed (*S. pacifica*). This assemblage is regularly observed within the upper end of many of the southern California coastal lagoons and near the broadened, alluvial mouths of coastal streams and riverine systems. Development of this habitat is fostered by sandy soil sedimentation over highly saline soils, or highly alkaline inputs to moist fluvial sediment deposits, such as from heavy livestock use. This habitat reflects the middle successional stages of conversion of salt marsh habitat to an upland community and was present in similar form prior to the initiation of the Batiquitos Lagoon restoration project. Following restoration, the acreage fluctuated slightly, but remained essentially unchanged at approximately seven acres in 2006.

<u>Brackish Marsh</u>

Thickets of California bulrush (*Schoenoplectus californicus*), intermixed with broad-leafed cattail (*Typha latifolia*), prairie bulrush (*Bolboschoenus maritimus*), southwestern spiny rush (*Juncus acutus*), salt marsh fleabane, and the marsh weed spearscale (*Atriplex prostrata*) defined much of the brackish marsh that occurred primarily eastward of the E-3 island nesting site in the east basin. Coverage of this vegetation type declined steadily following the introduction of tidal influence in 1997. Initially, large stands of dead and dying brackish marsh were prevalent at the mouth of San Marcos Creek, along the southeastern side of the east basin. As plants decayed, large bare mudflats appeared and were quickly colonized by *S. pacifica*. By year 10 (2006), patches of brackish marsh still persisted along the boundary of freshwater marsh and coastal salt marsh habitats within the southern and eastern portions of the east basin. The ratios of brackish, freshwater, and coastal salt marsh fluctuated from year to year in response to freshwater input, tidal muting, and elevated sea level conditions associated with El Niño periods.

Freshwater Marsh

The freshwater marsh at Batiquitos Lagoon is composed primarily of southern cattail (*Typha domingensis*) and California bulrush. It was originally expected that the majority of the freshwater marsh within the lagoon in 1997 would convert to brackish marsh and eventually to southern coastal salt marsh. However, this habitat has continued to exist and expand in the east basin in areas of consistent freshwater input. The acreage of freshwater marsh lagoon-wide nearly doubled from approximately 22 to 40 acres over the 10-year monitoring period (Table 3-1). Freshwater marsh expanded into portions of the south shore of the east basin and persisted at the east end. Large areas of freshwater marsh also occur at areas of freshwater input on the north shore of the central basin in a drainage below a residential complex, in the east basin near the Batiquitos Lagoon Foundation Nature Center, and along the north shore of the east basin adjacent to the golf course. In addition, an artificial detention pond created to the north of the W-1 nesting site in the west basin (not part of the Batiquitos Lagoon restoration) was overtaken by cattails by 2003 (Figure 3-2c).

The expansion of freshwater marsh, despite the restoration of tidal saline conditions, suggests a relatively substantial and persistent dry season input of freshwater. Under post-restoration tidal conditions, groundwater near the lagoon became saline and now fluctuates around mean tide levels, with a dampening of the range with distance from the lagoon and lowered permeability of soils. Because of the higher density of the saline groundwater, freshwater inputs from ground or surface water flows run out over the groundwater instead of flowing directly into the groundwater pool. As a result, the same volume of freshwater discharge extends over a broader surface area and supports expanded freshwater wetlands.

While the expansion of freshwater habitat within the tidal lagoon environment was not a predicted outcome during project planning, it enhances the overall habitat mosaic and supports avian species, enhancing bird diversity at the lagoon. If these freshwater and brackish marsh elements were to extend over substantially greater areas into the intended salt marsh habitat, it might be prudent to excavate drainage channels to force interception and diversion of freshwater. However, in the present state, such an effort is not warranted.

Southern Willow Scrub

Areas of southern willow scrub at Batiquitos Lagoon are dominated by arroyo willow (*Salix lasiolepis*) and Goodding's willow (*Salix gooddingii*). The acreage of willows increased slightly over the 10-year monitoring period but remained limited to the same fringing areas above tidal influence near a freshwater source. Runoff and natural seepage from the steep hillsides to the south supported willows adjacent to La Costa Avenue along the middle of the southern shore of the east basin (Figures 3-2a-d). Other small areas of willow occur at the mouth of Encinitas and San Marcos Creeks, along the northern edge of the east basin south of the golf course, near the park-and-ride lot adjacent to the E-1 nesting site, and in the extreme northeastern corner of the lagoon adjacent to El Camino Real.

Tamarisk Scrub

Several concentrated stands of salt cedar (*Tamarix parviflora*) were tracked near the willows adjacent to La Costa Avenue along the middle of the southern shore of the east basin, as well as in a few locations behind the E-1 nesting site and on the south shore of the central basin. Salt cedar did not expand outside of these areas but did enlarge from 0.3 to 1.0 acre from year 1 to 7. By years 9 and 10 (2005 and 2006), it had stabilized to 0.4 acre. This introduced weedy tree is a noxious pest in other riparian systems in the region. It persists when water resources are erratic and other normally competitive trees and shrubs fail due to the irregularity of runoff (*e.g.*, within floodplains below dams) or where salinity or alkalinity toxicity kills other species. It appears that there were exotic species removal efforts behind nesting site E-1 in the later years of the monitoring program, including salt cedar, though the details of this effort are not known.

Diegan Coastal Sage Scrub

Much of the sage scrub remaining around the fringe of the lagoon is secondary regrowth from prior historic disturbances. These areas support minimal floristic diversity (particularly in the understory) and feature the regional dominants associated with this scrub type: California sagebrush (*Artemisia californica*), flat-top buckwheat (*Eriogonum fasciculatum*), and laurel sumac *(Malosma laurina*). The coastal sage scrub occurs as a linear swath that borders the wetlands along the shores of the eastern basin. At one location on the north side of the central basin, is a stand of minimally disturbed sage scrub situated on the steep flank of the hillside. This intact habitat supports such maritime succulent species as lady fingers (*Dudleya edulis*), lance-leaf dudleya (*Dudleya lanceolata*), and sea dahlia (*Coreopsis maritima*), as well as coast cholla (*Opuntia prolifera*) and coastal prickly pear (*Opuntia littoralis*). Other maritime succulent scrub vegetation is found along the railroad in the west basin and on the north slope of the west basin. The extent of this habitat has remained relatively stable at approximately 30 acres and is largely unaffected by the hydrogeomorphic processes that have occurred at lower elevations, though trails maintained down into the lagoon through this habitat by fisherman and dog-walkers in the west and central basins are a continual disturbance to the vegetation and its resident fauna.

Disturbed Upland

Some upland areas, particularly along the northeastern boundaries of the east basin, include a number of exotic plantings and horticultural escapees such as pampas grass (*Cortaderia jubata*), a highly invasive species. Elsewhere are other non-native species such as fan palm (*Washingtonia robusta*), Canary Island date palm (*Phoenix canariensis*), hottentot fig (*Carpobrotus edulis*), and giant reed (*Arundo donax*). This habitat was mapped primarily on the periphery of the lagoon, in areas of urban intrusion. It was additionally used on some of the nesting sites, where non-native weedy species such as horseweed (*Conyza canadensis*), pampas grass, and tree tobacco (*Nicotiana glauca*) had invaded. The area mapped as disturbed upland remained relatively constant over the monitoring period.

Non-native Grassland

Heavily disturbed grassy upland terrain borders the wetlands of Batiquitos Lagoon at various locations, particularly along the railroad tracks and the Interstate 5 (I-5) bridge. Eurasian grasses such as wild oats (*Avena barbata*) and weedy herbs such as filaree (*Erodium cicutarium* and *Erodium moschatum*) dominated these areas. A reduction in the area over time may have resulted from a change in designation to disturbed upland following shifts in dominant vegetation.

Eucalyptus Woodland

Stands of non-native Australian eucalyptus (*Eucalyptus* spp.) have been planted at many locations on the northern edge of the east basin and on the southern slopes overlooking the central basin. The allelopathic effects of chemicals secreted in the leaves of eucalyptus and the heavy leaf litter keep the understory within the eucalyptus woodlands relatively free of competing species. Several of the larger eucalyptus trees along the northern boundary of the east basin are used as a rookery for various heron species.

Decaying Vegetation

This vegetation category was added in 1998 to describe areas where brackish and freshwater marsh were dying but were not in transition to coastal salt marsh. Decaying vegetation was mapped along the southern shore of the central basin where part of a large stand of cattails had died. This habitat type was not utilized after 1999.

Trails/Developed Land

This habitat is an aggregation of all heavily disturbed anthropogenic features existing within or along the boundaries of Batiquitos Lagoon. Included among these features are roads, trails, and armored shoreline. For the most part, the extent and location of these features has been documented for the purpose of monitoring future expansion or reduction in impact area. Biological monitoring has not specifically focused on this mapping unit.

Direct comparison of the above 19 habitats to pre-restoration conditions is not possible due to differences in mapping techniques. However, some rough comparisons can be made to the habitat mapping undertaken as part of the Batiquitos Lagoon Enhancement Project, Final EIR/EIS (City of Carlsbad and U.S. Army Corps of Engineers 1990). Aerial photographs taken in 1988 were analyzed to divide the lagoon vegetation into consolidated habitat categories. Acreages of these categories were broken down as follows: open water (including both shallow and deep water, nontidal habitats), nontidal flats, nontidal coastal salt marsh (including pickleweed dominated vegetation located between +3.9 and +10.0 feet MLLW tidal elevation), brackish marsh (located along lower, more saline drainages and seeps), and brackish woodland (including willows located at higher elevations than brackish marsh). These acreages were then modified in the EIR/EIS (Volume 3) to re-estimate the open water and nontidal flats acreage to reflect what the condition would be if the lagoon were open to the ocean, using 1985 topographic contours. Open water areas were defined as those below –1.6 feet MLLW, and nontidal flats were defined as unvegetated areas between –1.6 and 5.4 feet MLLW. Post-restoration, the development of 19 different lagoon habitats was tracked. The 1997 (year 1) and 2006 (year 10) post-restoration habitat acreages were grouped to roughly align with the 1988 pre-restoration habitat condition features in Table 3-1. The 1997 and 2006 open water and mudflat acreages are not based on the habitat mapping, but rather are derived from elevation-based calculation in Chapter 2.

Table 3-2. Comparison of pre-restoration (1988), projected, and 2006 habitat acreages.

Habitat Type	**1988[1]**	**1988[2]**	**Habitat Type**	**1997[3]**	**2006[4]**
Open water (non-tidal)	354	0.2[5]	Open water (tidal)[7]	188	197
Non-tidal flats[6]	64	417	Salt panne	11	16
			Intertidal flats/sand beach/shoal/mudflat[7]	191	97
Coastal salt marsh (non-tidal pickleweed)	123	123	So. coastal salt marsh (pickleweed dominated)	66	118
			So. coastal salt marsh (cordgrass dominated)		53
Brackish emergent marsh	39	39	Brackish marsh/freshwater marsh/goldenbush	78	62
Brackish woodland (willows)	7	7	Brackish woodland (willows)		
Riparian woodland (freshwater/willows)	2	2	Southern willow scrub/tamarisk scrub	12	15
			Nesting site	43	33
Subtotal	589	588	Subtotal	589	591
Other habitat elements	60	61	Other habitat elements	60	58
Total (acres)	**649**	**649**	**Total (acres)**	**649**	**649**

[1] June 1998 assessment based on aerial photographs, not elevationally defined (City of Carlsbad/U.S. Army Corps of Engineers 1990).
[2] Re-assessment of June 1998 habitats assuming tidal condition using 1985 bathymetry (City of Carlsbad/U.S. Army Corps of Engineers 1990).
[3] Post-restoration habitats from present report combined to approximate City of Carlsbad/U.S. Army Corps of Engineers (1990) habitats.
[4] Habitats from present report combined to approximate City of Carlsbad/U.S. Army Corps of Engineers (1990) habitats.
[5] Areas below -1.6-feet MLLW
[6] Unvegetated areas between -1.6 and 5.4-feet MLLW
[7] Elevationally defined, based on predicted and true tidal range. 1997 & 2006 extents determined elevationally in Chapter 2.

Approximately 123 acres of coastal salt marsh habitat were present in 1988. By 2006, approximately 171 acres of coastal salt marsh were present, made up of 53 acres of cordgrass and 118 acres of pickleweed dominated salt marsh. The brackish marsh element increased by 59% after the restoration, due to expansion of cattail dominated marsh at the site of freshwater inputs into the lagoon. By 2006, the amount of willow-dominated habitats had increased approximately 40% from that noted in 1988 under pre-restoration conditions.

3.2.2 Salt Marsh Transect Monitoring

A list of species found during each monitoring year is presented in Table 3-3. The coverage of each plant taxa recorded along each high, middle, and low marsh elevation transect during the 10-year monitoring program is presented in Tables 3-4a, b, and c. The results of pre-restoration monitoring conducted by WRA using the same methodology in 1994 and 1996 are included in all tables and figures. The species found in the transects represent a subsample of the marsh communities at the lagoon; therefore, absence of a particular species from the transects does not necessarily mean that the species is not present at an undetected location in the lagoon. All references to pickleweed in the following text are *S. pacifica* unless otherwise noted.

At the high marsh transects, a total of eight species of salt marsh plants were found prior to the restoration, and seven were documented post-restoration (Table 3-4a). Species present prior to restoration, but not after, were western marsh rosemary (*Limonium californicum*) and Parish's pickleweed (*Arthrocnemum subterminale*) (Figure 3-4a). Cordgrass was the only new salt marsh species found after restoration. One brackish marsh species was present at high marsh transects pre-restoration (spearscale), and a second, southern cattail (included in the Other category in Figure 3-4a), was recorded for the first time at one site in 2001 and again in 2006 (Site 1). While this species is typically considered a freshwater marsh species, it occurs in some

Table 3-3. Plants observed on vegetation monitoring transects pre-restoration (1994 & 1996) and post-restoration (1997, 1998, 1999, 2001, & 2006).

Scientific Name	Common Name	August '94[1]	August '96[2]	September '97	October '98	September '99	September '01	September '06
COASTAL SALT MARSH								
Cressa truxillensis	Alkali weed	X	X	X	X	X	X	
Cuscuta salina	Salt marsh dodder	X			X	X	X	X
Distichlis spicata	Saltgrass	X	X	X	X	X	X	X
Frankenia salina	Alkali heath	X	X	X	X	X	X	X
Jaumea carnosa	Salty susan	X	X	X	X	X	X	X
Limonium californicum	Western marsh-rosemary		X					
Arthrocnemum subtermina	Parish's pickleweed	X						
Sarcocornia pacifica	Pacific pickleweed	X	X	X	X	X	X	X
Spartina foliosa	California cordgrass				X	X	X	X
BRACKISH MARSH								
Atriplex prostrata	Spearscale		X	X	X	X	X	X
Juncus acutus	Southwestern spiny rush		X			X	X	X
Bolboschoenus maritimus	Prairie bulrush	X	X		X	X	X	X
Pluchea odorata	Salt marsh fleabane				X	X	X	X
Schoenoplectus californicu	California bulrush							X
Typha domingensis	Southern cattail						X	X
OTHER SPECIES								
Ambrosia psilostachya	Western ragweed						X	X
*Apium graviolens**	Celery						X	X
Artemisia douglasiana	Mugwort	X						
Aster subulatus var. ligula	Slimaster				X	X	X	
*Atriplex semibaccata**	Australian saltbush						X	
Baccharis pilularis	Coyote bush				X	X	X	X
*Brassica nigra**	Black mustard				X			
*Cakile maritima**	European sea-rocket							X
*Carpobrotus edulis**	Hottentot fig						X	
*Chenopodium album**	Lamb's quarters	X	X					
Chrysanthemum cornarium	Garland				X			
*Cotula coronopifolia**	African brass buttons						X	
Heliotropium curassavicun	Salt heliotrope		X					X
Isocoma menziesii	Spreading goldenbush	X		X	X	X	X	X
Isocoma sedoides	San Diego Goldenbush						X	
*Melilotus albus**	White sweetclover				X			
*Melilotus indicus**	Sourclover			X	X			
Paspalum distichum	Common knottgrass						X	
*Picris echiodes**	Bristly ox-tongue				X	X		X
*Polypogon monspeliensis**	Annual beard grass	X			X	X	X	
*Raphanus sativus**	Wild radish			X				
*Rumex pulcher**	Fiddle dock				X			
*Sonchus oleraceus**	Common sow thistle	X				X		
Asteraceae sp.		X						
Poaceae sp.		X						
Poaceae sp.		X						
*Xanthium sp.**			X					
Ruderal species		X						
Total Number of Salt Marsh Species Reported		**7**	**6**	**5**	**7**	**7**	**7**	**6**
Total Number of Non-native Species Reported		**4**	**2**	**2**	**7**	**3**	**5**	**3**
Total Number of Species Reported		**17**	**12**	**9**	**20**	**17**	**23**	**19**

*Indicates non-native species
[1]Wetlands Research Associates 1994
[2]Wetlands Research Associates 1996

Table 3-4a. Percent Vegetation Cover and Soil/water Salinity at High Marsh Transects - Pre-restoration (1994 and 1996) and Post-restoration (1997- 2006)
Elevations in feet NGDV listed after transect number (based on WRA 1994).

HIGH MARSH TRANSECTS	EAST BASIN							CENTRAL BASIN							WEST BASIN							EAST BASIN							EAST BASIN							EAST BASIN							WEST BASIN					NUMBER OF						
	SITE 1							SITE 2							SITE 3							SITE 4							SITE 5							SITE 6							SITE 7					TRANSECTS						
	Transect 1 (4.48)							Transect 1 (4.33)							Transect 1 (3.88)***							Transect 1 (5.48)							Transect 1 (6.50)							Transect 1 (6.50)							Transect 3					WITH SPECIES PRESENT						
PLANT SPECIES	**1994**	**1996**	**1997**	**1998**	**1999**	**2001**	**2006**	**1994**	**1996**	**1997**	**1998**	**1999**	**2001**	**2006**	**1994**	**1996**	**1997**	**1998**	**1999**	**2001**	**2006**	**1994**	**1996**	**1997**	**1998**	**1999**	**2001**	**2006**	**1994**	**1996**	**1997**	**1998**	**1999**	**2001**	**2006**	**1994**	**1996**	**1997**	**1998**	**1999**	**2001**	**2006**	**1997**	**1998**	**1999**	**2001**	**2006**	**1994**	**1996**	**1997**	**1998**	**1999**	**2001**	**2006**
COASTAL SALT MARSH																																																						
Cressa truxillensis																																				21.5	28.5	8.0	5.0	9.5	11.5							1	1	1	1	1	1	
Cuscuta salina								13.5																																							10.5	1						1
Distichlis spicata					2.5	4.5	4.5	1.5							10.0						26.0								21.5	14.0	27.0	27.5	24.0	34.0	9.5	13.0	5.5	12.5	54.5	46.5	50.0					12.5		4	2	2	2	3	4	3
Frankenia salina	84.0	25.0		2.0	8.5	29.0	100.0	91.5			2.5		5.5	5.0	5.0	3.0	6.5					36.5	28.5	30.0	38.5	53.5	62.5	80.5	13.5	41.5	5.0	9.0	8.0	29.5	35.0	34.0	20.5	14.5	18.0	24.5	36.5	37.5		17.0	4.0	47.5	4.5	6	5	4	6	5	6	6
Jaumea carnosa								8.0																					61.5	48.0	19.5	36.5	27.5	59.0	68.0	22.0	3.5	1.0	15.0	20.0	34.5	84.5		0.5	2.5	19.0	82.5	3	2	2	3	3	3	3
Limonium californicum																														0.5																			1					
Arthrocnemum subterminale																																				2.5												1						
Sarcocornia pacifica	45.5	13.0	23.0	45.5	49.5	73.5	11.5	18.5	21.0	89.0	100.0	100.0	100.0	100.0	89.5	16.5	86.5	80.0	88.5	94.0	73.0	26.0	37.0	60.0	64.0	56.0	57.5	27.5	39.5	57.0	43.5	48.0	66.0	48.5	32.5	20.0	73.0	72.5	53.5	50.0	35.0	32.0	74.5	73.0	85.0	64.0	2.0	6	6	7	7	7	7	7
BRACKISH MARSH																																																						
Atriplex prostrata		8.0	74.0	68.5	39.0					7.5						1.5	4.5				13.0	18.5	50.5	14.0	2.5											21.0	3.0	0.5	1.0				16.5					2	4	6	3	1		1
Pluchea odorata																																								2.5	2.5	1.0										1	1	1
*Typha domingensis***						0.5	0.5																																														1	1
OTHER SPECIES																																																						
Ambrosia psilostachya																																									7.5	3.5											1	1
*Apium graviolens**																																									2.5	4.5											1	1
Artemisia douglasiana																																				3.0												1						
Aster subulatus var. ligulatus																																							19.0	11.0	3.0										1		1	
*Atriplex semibaccata**																																														2.5							1	
Baccharis pilularis																									2.5	8.5	10.5	1.5																							1	1	1	1
*Brassica nigra**																																0.5																			1			
*Carpobrotus edulis**																																														3.5	13.5						1	1
*Chenopodium album**		22.0																																															1					
*Chrysanthemum cornarium**				2.0																																			2.5												2			
Heliotropium curassavicum		1.0																																													1.5		1					1
Isocoma menziesii					7.0																								3.5		17.5	14.5	14.0	4.0	6.0													1		1	1	2	1	1
Isocoma sedoides						6.0																																															1	
*Melilotus albus**																																18.0																			1			
*Melilotus indicus**																													2.5		4.5																	1		1				
*Picris echiodes**																												1.0				1.5								0.5											1	1		1
*Polypogon monspeliensis**																																5.5	5.0																		1	1		
*Raphanus sativus**																															1.0																			1				
*Rumex pulcher**				1.5																																															1			
*Sonchus oleraceus**																																				1.0				2.0								1				1		
Dead plant matter		31.0				0.5			24.5							83.0	5.0						4.0	8.0	5.0	8.5	3.5	9.0		3.5				4.0	1.0		7.0							5.0					6	2	2	1	3	2
Bare space/Open water		12.5	8.0					4.5	56.5	5.0						1.5	13.0	19.5	11.5	6.0	6.5								20.5	6.5							0.5	0.5					12.0	11.0	12.5	1.5	3.0	2	5	5	2	2	2	2
Total Vegetative Cover	**129.5**	**69.0**	**97.0**	**119.5**	**106.5**	**113.5**	**116.5**	**133.0**	**21.0**	**96.5**	**102.5**	**100.0**	**105.5**	**105.0**	**104.5**	**21.0**	**97.5**	**80.0**	**88.5**	**94.0**	**112.0**	**81.0**	**116.0**	**104.0**	**107.5**	**118.0**	**130.5**	**110.5**	**142.0**	**161.0**	**118.0**	**161.0**	**144.5**	**175.0**	**151.0**	**138.0**	**134.0**	**109.0**	**168.5**	**166.5**	**183.0**	**163.0**	**91.0**	**90.5**	**91.5**	**149.0**	**114.5**							
Soil or Water Salinity (ppt)	65	61.5						39.5	53.5	34		82		54	118	120	37	55	56		51	11.5	83.5						104	103						18	32					50	37			38								

Shaded columns indicate surveys completed prior to restoration completion
*Non-native species
** Freshwater marsh species located on edge of brackish marsh
*** WRA (1994) reported Site 3 Transect 1 as high marsh at an elevation of 3.88 feet NGVD. Field observation found Transect 1 to be higher than Transect 2, which was reported as 4.25 feet NGVD. Error assumed. For the present study Transect 1 always treated as the high marsh transect.

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Table 3-4b. Percent Vegetation Cover and Soil/water Salinity at Middle Marsh Transects - Pre-restoration (1994 and 1996) and Post-restoration (1997-2006)
Elevations in feet NGDV listed after transect number (based on WRA 1994).

MIDDLE MARSH TRANSECTS	EAST BASIN SITE 1 Transect 2 (3.48)							EAST BASIN SITE 1 Transect 3 (2.63)						
PLANT SPECIES	**1994**	**1996**	**1997**	**1998**	**1999**	**2001**	**2006**	**1994**	**1996**	**1997**	**1998**	**1999**	**2001**	**2006**
COASTAL SALT MARSH														
Cressa truxillensis														
Cuscuta salina														
Distichlis spicata														
Frankenia salina	32.0	4.0		2.0	2.0	19.5	28.5		9.5					
Jaumea carnosa														
Sarcocornia pacifica	84.5	7.5	74.0	100.0	100.0	100.0	81.0	21.0	32.5	15.5	43.0	53.5	76.5	59.5
Spartina foliosa													17.5	33.0
BRACKISH MARSH														
Atriplex prostata		48.5	8.5	2.0		0.5			7.0					
Bolboschoenus maritimus											4.0			
Juncus acutus														
Pluchea odorata														
Schoenoplectus californicus														
*Typha domingensis***														
OTHER SPECIES														
Aster subulatus var. ligulatus														
*Chenopodium album**		9.0												
*Cotula coronopifolia**														
Isocoma menziesii														
*Melilotus indicus**														
Paspalum distichum														
*Picris echiodes**														
*Polypogon monspeliensis**														
Dead plant matter		31.5							41.5					
Bare space/Open water	1.5	9.5	17.5					98.5	15.5	84.5	57.0	46.5	12.5	12.0
Total Vegetative Cover	**116.5**	**69.0**	**82.5**	**104.0**	**102.0**	**120.0**	**109.5**	**21.0**	**49.0**	**15.5**	**47.0**	**53.5**	**94.0**	**92.5**
Soil or Water Salinity (ppt)	65.5	46			66	52	55	37.7	102	45	47.5		62	39

MIDDLE MARSH TRANSECTS	CENTRAL BASIN SITE 2 Transect 2 (3.13)							WEST BASIN SITE 3 Transect 2 (4.25)***						
PLANT SPECIES	**1994**	**1996**	**1997**	**1998**	**1999**	**2001**	**2006**	**1994**	**1996**	**1997**	**1998**	**1999**	**2001**	**2006**
COASTAL SALT MARSH														
Cressa truxillensis									1.0					
Cuscuta salina								5.0						
Distichlis spicata								24.0						
Frankenia salina							35.5	32.0	1.5					
Jaumea carnosa														
Sarcocornia pacifica	99.5		73.0	100.0	100.0	100.0	71.5	77.0	94.0	17.0			1.0	41.0
Spartina foliosa														1.0
BRACKISH MARSH														
Atriplex prostata			8.0						4.5					
Bolboschoenus maritimus														
Juncus acutus														
Pluchea odorata														
Schoenoplectus californicus														
*Typha domingensis***														
OTHER SPECIES														
Aster subulatus var. ligulatus														
*Chenopodium album**														
*Cotula coronopifolia**														
Isocoma menziesii														
*Melilotus indicus**														
Paspalum distichum														
*Picris echiodes**														
*Polypogon monspeliensis**														
Dead plant matter		99.5							10.5					
Bare space/Open water		1.5	20.0							85.0	100.0	100.0	100.0	58.5
Total Vegetative Cover	**99.5**	**0.0**	**81.0**	**100.0**	**100.0**	**100.0**	**107.0**	**138.0**	**101.0**	**17.0**	**0.0**	**0.0**	**1.0**	**42.0**
Soil or Water Salinity (ppt)	20	45.5	34					56.5	118	36	45		40	45

MIDDLE MARSH TRANSECTS	EAST BASIN SITE 4 Transect 2 (2.63)							EAST BASIN SITE 5 Transect 2					EAST BASIN SITE 5 Transect 3 (2.75)						
PLANT SPECIES	**1994**	**1996**	**1997**	**1998**	**1999**	**2001**	**2006**	**1997**	**1998**	**1999**	**2001**	**2006**	**1994**	**1996**	**1997**	**1998**	**1999**	**2001**	**2006**
COASTAL SALT MARSH																			
Cressa truxillensis																			
Cuscuta salina									0.5	2.5	15.0								
Distichlis spicata								3.5	6.5	14.5	41.0								
Frankenia salina								9.0	8.0	5.0	9.5								
Jaumea carnosa								10.0	18.5	31.0	31.0								
Sarcocornia pacifica	98.0		16.0	58.5	54.0	57.5	42.5	25.5	50.5	31.5	38.0	5.0	49.0		5.5	23.0	36.5	26.0	49.5
Spartina foliosa																			
BRACKISH MARSH																			
Atriplex prostata									2.0						22.5	5.0			
Bolboschoenus maritimus						1.0							20.0	3.0		18.5	20.0	89.0	99.0
Juncus acutus																			
Pluchea odorata																			
Schoenoplectus californicus							6.0												
*Typha domingensis***							22.5												
OTHER SPECIES																			
Aster subulatus var. ligulatus									3.0										
*Chenopodium album**																			
*Cotula coronopifolia**						2.5													
Isocoma menziesii									1.0										
*Melilotus indicus**									1.0										
Paspalum distichum						0.5													
*Picris echiodes**																			
*Polypogon monspeliensis**									3.0		2.0								
Dead plant matter		5.0				18.0								42.5					
Bare space/Open water	17.5	100.0	84.0	46.0	44.0	21.5		55.5	30.0	38.5	34.5	95.0	92.5	60.5	63.0	56.0	44.5	7.5	7.0
Total Vegetative Cover	**98.0**	**0.0**	**16.0**	**58.5**	**54.0**	**61.5**	**71.0**	**48.0**	**94.0**	**84.5**	**136.5**	**5.0**	**69.0**	**3.0**	**28.0**	**46.5**	**56.5**	**115.0**	**148.5**
Soil or Water Salinity (ppt)	35.5	47	36	61	56	42	31						61.5	90	51	71		46	32

MIDDLE MARSH TRANSECTS	EAST BASIN SITE 6 Transect 2 (4.25)							WEST BASIN SITE 7 Transect 1						
PLANT SPECIES	**1994**	**1996**	**1997**	**1998**	**1999**	**2001**	**2006**	**1994**	**1996**	**1997**	**1998**	**1999**	**2001**	**2006**
COASTAL SALT MARSH														
Cressa truxillensis														
Cuscuta salina														
Distichlis spicata	1.5	2.0	2.5	3.5	5.5	14.5	4.5	10.0						
Frankenia salina	11.5	14.5	12.5	6.5	8.0	6.5	2.0	35.0						
Jaumea carnosa					2.0	56.5	100.0							
Sarcocornia pacifica	63.0	69.5	74.0	95.0	93.5	72.0	5.0	71.5	0.5	63.5	86.0	67.0	62.0	
Spartina foliosa														
BRACKISH MARSH														
Atriplex prostata														
Bolboschoenus maritimus					0.5									
Juncus acutus					2.5	30.0	84.5							
Pluchea odorata				2.5		1.0								
Schoenoplectus californicus														
*Typha domingensis***														
OTHER SPECIES														
Aster subulatus var. ligulatus				1.5	0.5	0.5								
*Chenopodium album**														
*Cotula coronopifolia**														
Isocoma menziesii														
*Melilotus indicus**														
Paspalum distichum														
*Picris echiodes**					1.0									
*Polypogon monspeliensis**				1.0	23.5	5.5								
Dead plant matter									79.0				2.0	
Bare space/Open water	84.5	25.5	14.5					0.5	27.0	32.0	14.0	33.0	36.0	100.0
Total Vegetative Cover	**76.0**	**86.0**	**89.0**	**110.0**	**137.0**	**186.5**	**196.0**	**116.5**	**0.5**	**63.5**	**86.0**	**67.0**	**62.0**	**0.0**
Soil or Water Salinity (ppt)	89	164			>100	41	35	24	27	33	39	45	35	

MIDDLE MARSH TRANSECTS	EAST BASIN SITE 8 Transect 2					EAST BASIN SITE 8 Transect 3					NUMBER OF TRANSECTS WITH SPECIES PRESENT						
PLANT SPECIES	**1997**	**1998**	**1999**	**2001**	**2006**	**1997**	**1998**	**1999**	**2001**	**2006**	**1994**	**1996**	**1997**	**1998**	**1999**	**2001**	**2006**
COASTAL SALT MARSH																	
Cressa truxillensis												1.0					
Cuscuta salina											1.0			1	1	1	
Distichlis spicata											3.0	1.0	2	2	2	2	1
Frankenia salina	3.0		12.0	1.0	69.5				26.0	18.0	4.0	4.0	3	3	4	5	5
Jaumea carnosa													1	1	2	2	1
Sarcocornia pacifica	79.5	100.0	72.0	100.0	39.5	53.5	100.0	100.0	96.0	82.5	8	5.0	11	10	10	10	10
Spartina foliosa																1	2
BRACKISH MARSH																	
Atriplex prostata	13.0					24.5				37.0		3.0	5	3		1	1
Bolboschoenus maritimus											1	1.0		2	2	2	1
Juncus acutus															1	1	1
Pluchea odorata														1		1	
Schoenoplectus californicus																	1
*Typha domingensis***																	1
OTHER SPECIES																	
Aster subulatus var. ligulatus														2	1	1	
*Chenopodium album**												1.0					
*Cotula coronopifolia**																1	
Isocoma menziesii														1			
*Melilotus indicus**														1			
Paspalum distichum																1	
*Picris echiodes**															1		
*Polypogon monspeliensis**														2	1	2	
Dead plant matter												7.0				2	
Bare space/Open water	7.5					15.5					6	7.0	11	6	6	5	5
Total Vegetative Cover	**95.5**	**100.0**	**84.0**	**101.0**	**109.0**	**78.0**	**100.0**	**100.0**	**122.0**	**137.5**							
Soil or Water Salinity (ppt)	77		87			51											

Shaded columns indicate surveys completed prior to restoration completion
*Non-native species
** Freshwater marsh species located on edge of brackish marsh

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Table 3-4c. Percent Vegetation Cover and Soil/water Salinity at Low Marsh Transects - Pre-restoration (1994 and 1996) and Post-restoration (1997-2006)
Elevations in feet NGDV listed after transect number (based on WRA 1994).

LOW MARSH TRANSECTS	EAST BASIN							CENTRAL BASIN							EAST BASIN						
	SITE 1							SITE 2							SITE 4						
	Transect 4 (2.13)							Transect 3 (2.00)							Transect 3 (2.25)						
PLANT SPECIES	**1994**	**1996**	**1997**	**1998**	**1999**	**2001**	**2006**	**1994**	**1996**	**1997**	**1998**	**1999**	**2001**	**2006**	**1994**	**1996**	**1997**	**1998**	**1999**	**2001**	**2006**
COASTAL SALT MARSH																					
Sarcocornia pacifica	4.5		15.5	2.0	11.0	85.5	56.0													1.0	50.0
Spartina foliosa				3.0	21.0	49.0	97.5													3.0	74.5
BRACKISH MARSH																					
Bolboschoenus maritimus																					
Schoenoplectus robustus																					
Dead plant matter									7.5												
Bare space/Open water	100.0	100.0	84.5	92.0	63.0	3.0	0.0	100.0	94.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	96.0	12.0
Total Vegetative Cover	**4.5**	**0.0**	**15.5**	**5.0**	**32.0**	**134.5**	**153.5**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**4.0**	**124.5**
Soil or Water Salinity (ppt)	12	18	33	33	47	50	41	14	67	34	41	43	35	34	14	24	36	47	58	58	37

LOW MARSH TRANSECTS	EAST BASIN							EAST BASIN							WEST BASIN							EAST BASIN							NUMBER OF						
	SITE 5							SITE 6							SITE 7							SITE 8							TRANSECTS						
	Transect 4 (2.13)							Transect 3 (2.13)							Transect 2							Transect 1							WITH SPECIES PRESENT						
PLANT SPECIES	**1994**	**1996**	**1997**	**1998**	**1999**	**2001**	**2006**	**1994**	**1996**	**1997**	**1998**	**1999**	**2001**	**2006**	**1994**	**1996**	**1997**	**1998**	**1999**	**2001**	**2006**	**1994**	**1996**	**1997**	**1998**	**1999**	**2001**	**2006**	**1994**	**1996**	**1997**	**1998**	**1999**	**2001**	**2006**
COASTAL SALT MARSH																																			
Sarcocornia pacifica						37.5	16.0							27.0			0.5												1		2	1	1	3	4
Spartina foliosa							100.0							53.0																		1	1	2	4
BRACKISH MARSH																																			
Bolboschoenus maritimus														1.5																					1
Schoenoplectus robustus	5.5																												1						
Dead plant matter																														1					
Bare space/Open water	99.0	100.0	100.0	100.0	100.0	62.5	100.0	100.0	100.0	100.0	100.0	100.0	100.0	35.5	100.0	100.0	99.5	100.0	100.0	100.0	100.0			100.0	100.0	100.0	100.0	100.0	6	5	7	7	7	7	
Total Vegetative Cover	**5.5**	**0.0**	**0.0**	**0.0**	**0.0**	**37.5**	**116.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**81.5**	**0.0**	**0.0**	**0.5**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**							
Soil or Water Salinity (ppt)	23	28	40	35	36	45	40		72	70				74	14	14.5	33	44		35	35			35	45		45	40							

Shaded columns indicate surveys completed prior to restoration completion
*Non-native species
** Freshwater marsh species located on edge of brackish marsh

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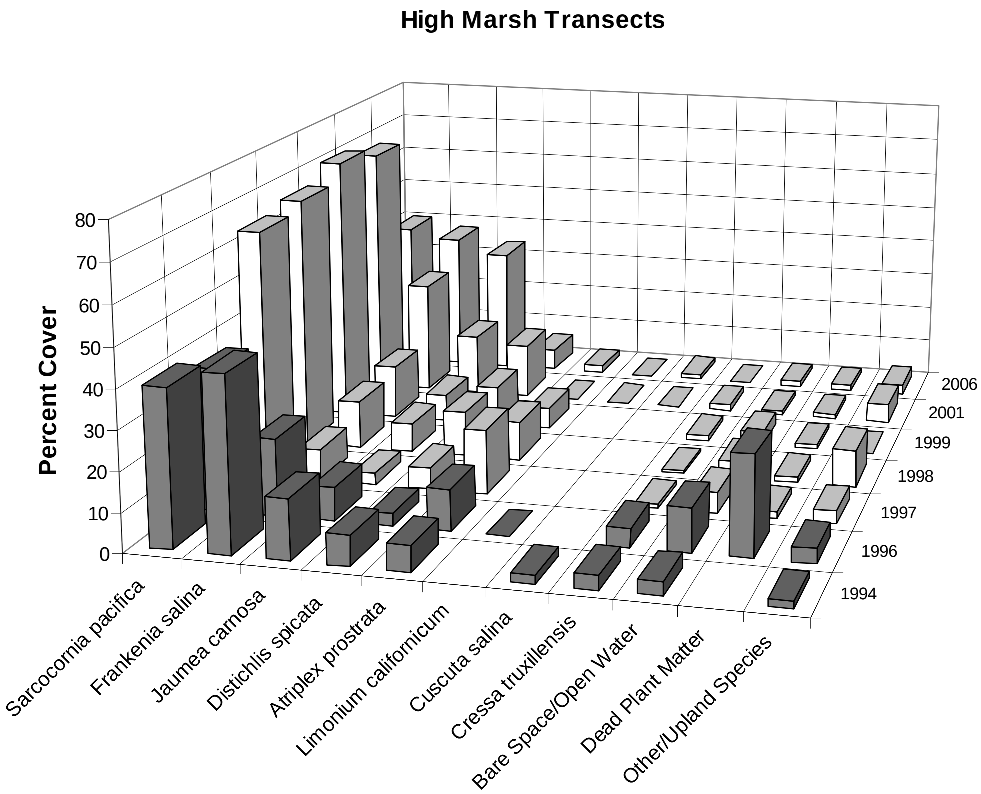

Figure 3-4a. Average percent cover of marsh species at high marsh transects pre-restoration (1994 and 1996) and post-restoration (1997-2006).

areas of brackish marsh at Batiquitos Lagoon where incoming perennial freshwater flow dilutes hypersaline soils to the point that freshwater marsh can become established and persist.

Overall, the percent cover of pickleweed increased post-restoration at the high marsh transects (Figure 3-4a). The drop in pickleweed cover during year 10 was the result of a large expansion of alkali heath and salty Susan. The cover of the brackish marsh spearscale initially increased post-restoration, then declined through year 10 as more competitive tidal salt marsh species expanded. Following restoration, the number of non-native species in the high marsh increased from 3 to 11, with species such as annual beard grass (*Polypogon monspeliensis*), white sweetclover (*Melilotus albus*), and hottentot fig present in some transects.

All high marsh transects became nearly fully vegetated by year 10, with limited bare ground (Table 3-4a). The most diverse high marsh transects were found at Sites 5 and 6 in the east basin (supporting four and five salt marsh species, respectively) and at Site 7 in the west basin (five species). Site 2 in the central basin and Site 4 in the east basin were consistently the least diverse, supporting only pickleweed and alkali heath post-restoration.

The middle marsh transects supported a total of five species of salt marsh plants prior to the restoration and six species post-restoration, with the loss of alkali weed (*Cressa truxillensis*) and the addition of salty Susan and Pacific cordgrass (Figure 3-4b). Site 6 was the most diverse, with four salt marsh and three brackish marsh species. This transect included a large expanse of southwestern spiny rush.

Of the 11 middle marsh transects, 3 supported only 1 salt marsh species (pickleweed) and 4 supported only 2 salt marsh species. Following restoration, the number of non-native species in the middle marsh increased from only lamb's quarters (*Chenopodium album*) to four non-native species, the most abundant of which was annual beard grass at Site 6.

The middle marsh transects were more dynamic than in the high marsh. At Site 3 in the west basin, pickleweed expanded between years 5 and 10 to vegetate the previously 100% bare transect with 41% pickleweed and 1% cordgrass. At the other west basin site (Site 7 on the north shore), the transect lost all of its pickleweed over the 10-year period as the marsh eroded and the site became a sand beach (see Chapter 2, Figure 2-11). The salt marsh in Transect 2 at Site 5 in the east basin was lost between years 5 (2001) and 10 (2006), with pickleweed cover dropping from 50% to 5%. The slightly higher transect 3 at the same site expanded pickleweed cover from 6% to 50% by year 10. Site 4 in the east basin was colonized by southern cattail in year 10, reducing the amount of bare mudflat and pickleweed on the transect. The remaining transects showed an increase in percent cover of pickleweed, with a reduction in year 10 as it was displaced by cordgrass or alkali heath.

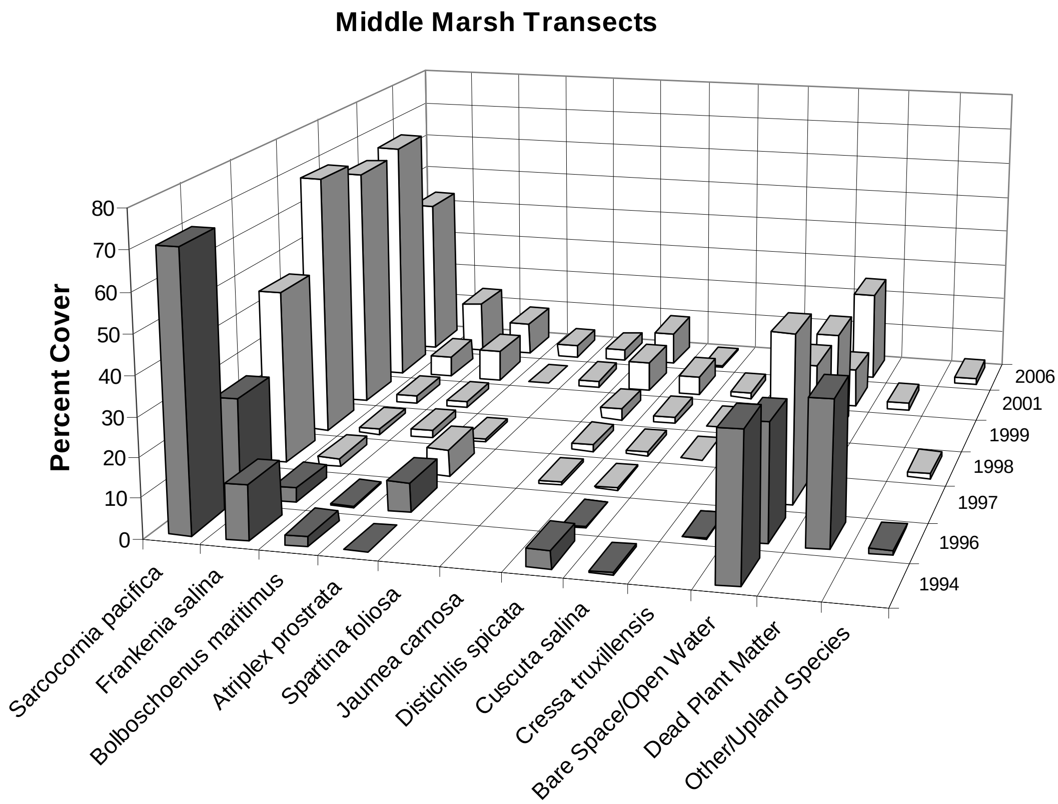

Figure 3-4b. Average percent cover of marsh species at middle marsh transects pre-restoration (1994 and 1996) and post-restoration (1997-2006).

The low marsh transects were the least diverse and least vegetated (Figure 3-4c). Two of the low marsh transects that were unvegetated prior to the restoration remained unvegetated after tidal influence was restored (Site 2 and 8) (Table 3-4c). Sites 4 and 5 were bare until year 5 (2001) and Site 6 until year 10 (2006), at which time some pickleweed and cordgrass became established. The cordgrass in these transects recruited from the seed of plants at transplant sites at other locations. No non-native species were found in the low marsh transects. California bulrush was present at Site 5 in 1994 but was not observed post-restoration. The brackish marsh species, prairie bulrush, was found in small amounts in year 10 at Site 6.

Figures 3-5a through 3-5h illustrate the changes in the vegetation community with photographs taken at fixed locations at each transect monitoring site during pre-restoration (1994 and 1996) and post-restoration (1997 to 2006) years.

Total organic carbon (TOC) measured in sediments collected from each transect is presented in Figure 3-6. The raw data can be found in Appendix A3-2. The mean TOC at the high marsh transects increased during each monitoring year, from a mean of 8,560 mg/kg in year 1 (1997) to a mean of 30,428 mg/kg in year 10 (2006). The mean TOC at the mid marsh transects increased

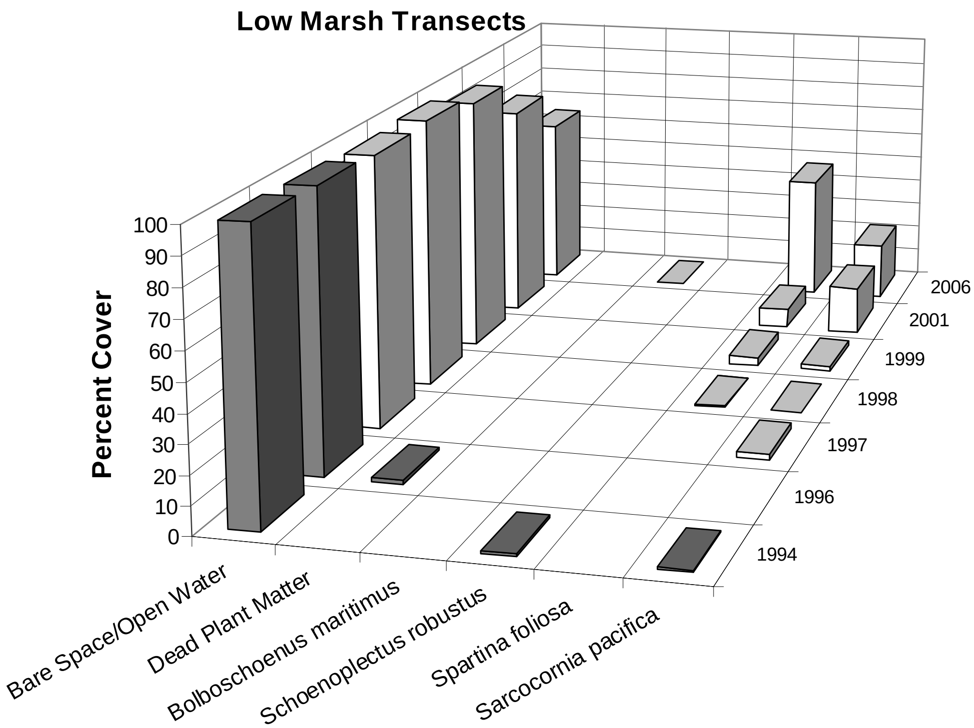

Figure 3-4c. Average percent cover of marsh species at low marsh transects pre-restoration (1994 and 1996) and post-restoration (1997-2006).

from 9,232 mg/kg in year 1 to 28,536 mg/kg in year 5 (2001), then back down to 15,645 mg/kg in year 10 (2006). TOC showed no trend over time at the low elevations, with means of 7,728 mg/kg, 4,773 mg/kg, 8,971 mg/kg, 8,942 mg/kg, and 17,700 in years 1 (1997), 2 (1998), 3 (1999), 5 (2001), and 10 (2006), respectively. The results of the grain size analysis from each transect are provided in Appendix A3-3.

1994

1996

1997

1998

1999

2001

2006

N
W E
S

Vegetation transect, site 1
pre-restoration (1994 and 1996)
and post-restoration (1997-2006)

Figure3-5a

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1994

1996

1997

1998

1999

2001

2006

N
W E
S

Vegetation transect, site 2
pre-restoration (1994 and 1996)
and post-restoration (1997-2006)

Figure3-5b

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1994

1996

1997

1998

1999

2001

2006

Vegetation transect, site 3
pre-restoration (1994 and 1996)
and post-restoration (1997-2006)

Figure3-5c

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1994

1996

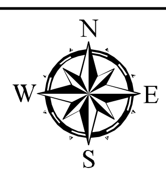
1997

1998

1999

2001

2006



Vegetation transect, site 4
pre-restoration (1994 and 1996)
and post-restoration (1997-2006)

Figure3-5d

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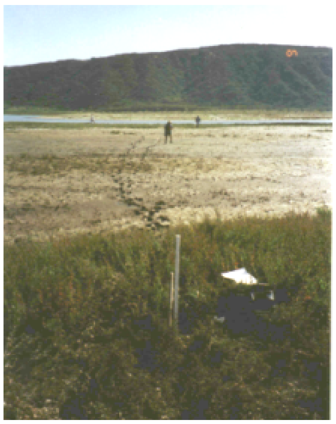
1994

1996

1997



1998

1999

2001

2006

N
W E
S

Vegetation transect, site 5
pre-restoration (1994 and 1996)
and post-restoration (1997-2006)

Figure3-5e

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1994

1996

1997

1998

1999

2001

2006

Vegetation transect, site 6
pre-restoration (1994 and 1996)
and post-restoration (1997-2006)

Figure3-5f

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1994

looking west

1996

looking west

1997

looking north

1998

looking south

1999

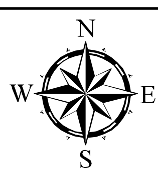
looking south

2001

looking south

2006

looking south



Vegetation transect, site 7
pre-restoration (1994 and 1996)
and post-restoration (1997-2006)

Figure3-5g

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1997

looking south

1998

looking west

1999

looking west

2001

looking west

2006

looking west

N
W E
S

Vegetation transect, site 8
post-restoration (1997-2006)
Site 8 was added to monitoring program in 1997

Figure3-5h

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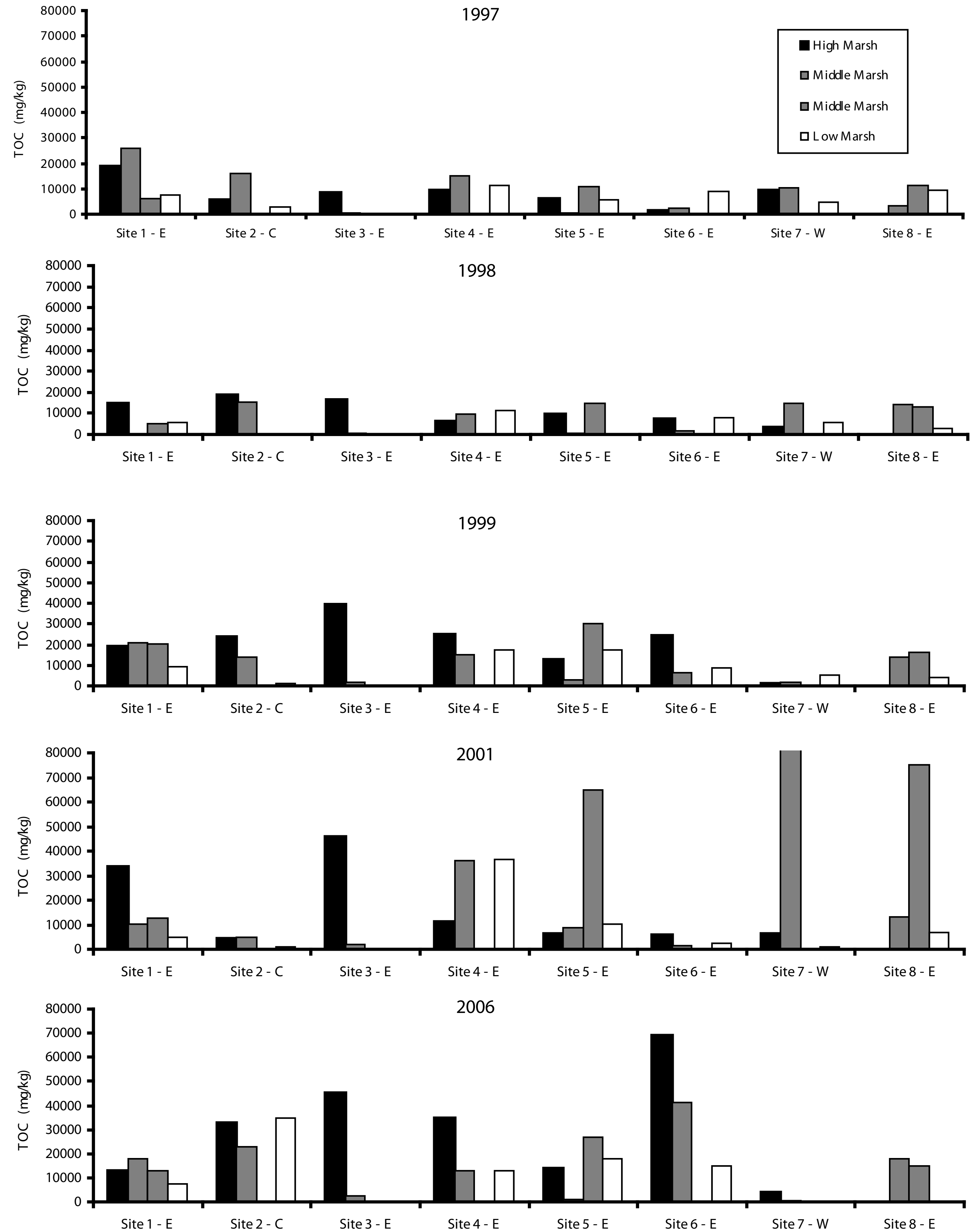

Total organic carbon at vegetation monitoring sites
E = East Basin, C = Central Basin, W = West Basin
NC = Not Collected

Figure 3-6

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3.3 DISCUSSION

Vegetation is often the defining component in the classification of habitats. Vegetation provides structure that is often critical to the existence of other organisms by providing protection from predators, modifying microclimates to produce favorable conditions for other species, providing a place to rest on or attach to, or providing raw material for functions such as nest building. In addition to their physical roles, plants (and algae) are the primary producers for nearly all habitats on Earth. They form the base of most food webs, providing energy to support detrital and consumer based trophic interactions. Ultimately, it is the primary production of plants that allows for the existence of other organisms within most ecological communities.

At Batiquitos Lagoon, a desirable balance of vegetation communities developed following the restoration. By year 10 (2006), the majority of the expansion of the various marsh habitats had been completed. Future years are likely to reveal an expansion and contraction of these fresh and saltwater habitats based on tidal, freshwater, and physical conditions that will vary between years. The communities are distinct and expansive, and each provides unique structural and trophic values that combine to form a diverse and comprehensive suite of habitats within the lagoon.

As expected, one of the largest changes in vegetation communities since the lagoon opening has been the transition of brackish marsh and intertidal mudflat to southern coastal salt marsh, dominated either by pickleweed or cordgrass. Large gains in pickleweed dominated salt marsh occurred in the eastern portion of the east basin, where brackish marsh gave way to pickleweed as tidal influence stabilized soil moisture, salinity, and ORP gradients to areas of previously unpredictable and variable physical conditions. Pickleweed also expanded in the east and central basins down onto unvegetated mudflat, an expansion that was nearly complete by year 7 (2003) (Figure 3-3c), with a 72% increase in pickleweed acreage from 1996 to 2003.

Prior to restoration, the coastal salt marsh was less diverse than other marshes in southern California. Zedler (1982) reported that Batiquitos Lagoon supported 10 salt marsh species, while other marshes supported more: Tijuana Estuary (18 species), Sweetwater Marsh in San Diego Bay (17 species), Los Peñasquitos Lagoon (12 species), and San Dieguito Lagoon (12 species). Pre-restoration monitoring conducted by WRA (1994), at the same transects as the post-restoration monitoring, found a total of seven salt marsh species. Post-restoration, marsh diversity remained low (seven species), although physical environments to support higher marsh diversity appear to have been fully developed.

Zedler compared plant species diversity in 11 tidal coastal salt marshes to non-tidal coastal salt marshes in San Diego County and found that, with only one exception, tidal systems supported a higher number of species than the non-tidal marshes. In particular, four low to mid-marsh species were identified as distinguishing a tidal salt marsh from a non-tidal salt marsh: Pacific cordgrass, Bigelow's pickleweed (*Salicornia bigelovii*), saltwort (*Batis maritima*), and arrow grass (*Triglochin concinnum*). These species were absent from Batiquitos Lagoon prior to the restoration (Zedler 1982, California Coastal Conservancy 1987, WRA 1994, WRA 1997) and MacDonald (1977) attributed their absence to the lack of tidal influence in the lagoon. Although the restoration was undoubtedly expected to result in tidal and soil conditions that would support these additional four species, no provision was made to intentionally introduce them to the system, except for the cordgrass. Therefore, the only means for their arrival would be through natural dispersal by mechanisms such as transport by wind, birds, or mammals. The success observed with the introduction of cordgrass suggests introductions of other desirable marsh species may establish successfully within the restored system.

Diversity in the salt marsh species on the transects did not increase post-restoration. Parish's pickleweed and western marsh rosemary were lost from the transects, and only cordgrass was gained. For the first five years, the marsh was nearly monotypic pickleweed, with only limited occurrences of other species. By year 10 (2006), the alkali heath had displaced or overgrown a portion of the pickleweed on many transects, but other species remained relatively static.

Of the four species mentioned above as distinctive to salt marshes with tidal influence, only cordgrass was present after tidal influence was restored and the species was introduced to the lagoon. Along with the three species discussed above, other species that are supported in more diverse salt marshes, but which were also absent from Batiquitos Lagoon transects, included Watson's saltbush (*Atriplex watsonii*), yellow-ray goldenfields (*Lasthenia glabrata*), shoregrass (*Monanthochloe littoralis*), estuary sea-blite (*Suaeda esteroa*), and the endangered salt marsh bird's-beak (*Cordylanthus maritimus*). It is possible that these species occur outside of the monitoring transects at Batiquitos Lagoon, but they have not been detected by biologists conducting other monitoring efforts throughout the lagoon over the 10-year monitoring period.

Increased diversity within the salt marsh provides greater variability in structure, greater stability and resilience to disturbance (Lawton 1994, Naeem et al. 1995), and leads to a greater diversity of associated organisms at higher trophic levels (Lawton 1983). Without intentional reintroduction of these species to the lagoon, it is likely that the salt marsh will remain low in plant species diversity. It is important to note, however, that despite limited diversity in the salt marsh, the large expanses of pickleweed have continued to provide abundant nesting habitat for Belding's Savannah sparrow (*Passerculus sandwichensis beldingi)* (see Chapter 7). Zembal et al. (2006) noted that the pickleweed belt on the north and south shoreline of the east basin was too narrow to adequately accommodate Belding's Savannah sparrows. This belt of pickleweed will not widen in the future due to the proliferation of cordgrass at its lower boundary and upland plants or urban interface at its upper edge. However, during focused breeding season surveys, Belding's Savannah sparrows were documented to nest in these areas, suggesting that territories may be elongated to compensate for the narrow width of the tidal pickleweed band.

The number of non-native species found on the transects increased from four pre-construction to seven post-construction, primarily in the high marsh. It is possible that the conditions prior to restoration were too inhospitable for most weed species to become established, with periods of extended inundation followed by dry periods with hypersaline soils. Additionally, the high marsh transects are often in close proximity to disturbed uplands and the public footpath on the north shore of the lagoon, exposing those transects to adjacent weeds. Portions of the high marsh experience such infrequent inundation that some non-native species are able to persist. Non-natives reduce the quality of the salt marsh habitat but were not present in high enough densities to be of significant concern and were not commonly found in the adjacent marsh, although there is the potential for expansion of giant reed and pampas grass in the east basin if conditions are suitable.

As discussed above, the expansion of pickleweed onto the mudflat was slowed and even pushed back after 2003 by the spread of cordgrass up the flats to higher elevations. The spread of cordgrass also displaced open mudflat and pickleweed growing at low marsh elevations. This change was most evident on the northeast and southeast shorelines of the central basin, the salt marsh around nesting site E-1, and along the north and south shorelines of the east basin (Figures 3-3c and d). The expansion of cordgrass, the preferred habitat of the endangered light-footed clapper rail *(Rallus longirostris levipes)*, was so great (from 0.4 to 24.6 acres in 1998 to 2003) that in 2004 and 2005, captive bred clapper rails were released into the lagoon through a joint project between the Chula Vista Nature Center, SeaWorld, Dick Zembal, and the USFWS (see Chapter 7).

The shifts in the coverage of these habitat types are shown graphically in Figure 3-7. The figure shows the loss of pickleweed and its replacement by cordgrass. With the expansion of the salt marsh vegetation, unvegetated mudflat area was reduced.

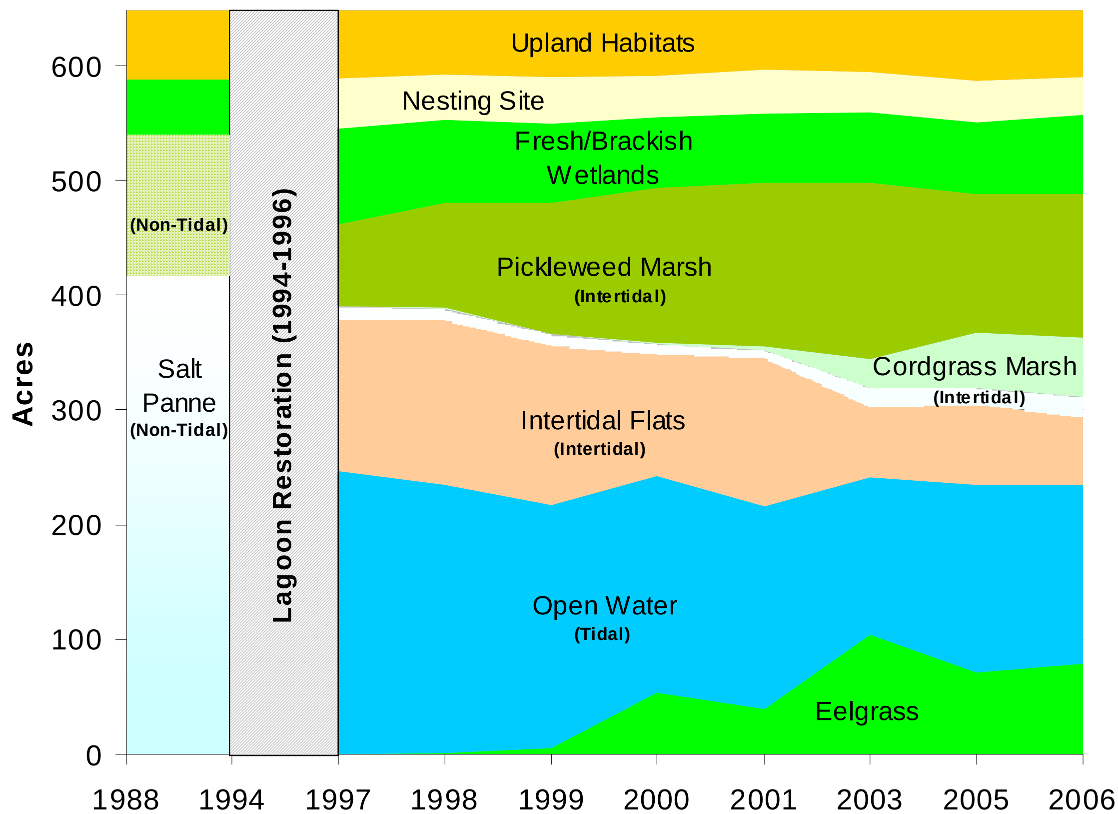

Figure 3-7. Development of habitats following restoration.

It is notable that the acreages of mudflat and salt marsh appear to have been relatively stable since 2003, suggesting the marsh development has stabilized, with nearly all available habitat occupied and mudflat acreage controlled more by physical forces (see Chapter 2) rather than biological forces. This balance is anticipated to fluctuate from year to year, resulting from maintenance dredging activities, the occurrence of other environmental response to storm event sediment loading, changes in tidal prism and inundation frequency stresses.

The present extent of salt marsh vegetation is determined by the current muted tidal condition. The muting of the system over time has the effect of narrowing the tidal range in a manner that increases the frequency of inundation throughout all but the extreme high end of the intertidal zone. This can result in an elevation and compression of the classical intertidal estuary zonation patterns such that low marsh vegetation such as cordgrass (typically extending to a low elevation near mean sea level) is raised higher on the shoreline and begins to displace middle marsh vegetation such as pickleweed occurring within normal elevation ranges. The middle marsh is then pushed upward as well and displaces some of the higher marsh vegetation. The higher marsh remains limited at the upper boundary by saline influences that prevent terrestrial vegetation from effectively competing with salt tolerant marsh plants. The distribution and vertical extent of the mudflat and low and middle marsh will fluctuate over time in response to tidal muting and tide range restoration maintenance actions (inlet dredging).

The expansion of eelgrass from the original transplant sites into all basins has provided additional habitat complexity to the lagoon system, serving as a primary producer in the lagoon food web and a food source for invertebrates, fish, and birds, thus contributing to eco-system health at multiple trophic levels. The success of the transplant has provided additional insight into the early expansion patterns of eelgrass transplants, the ability of eelgrass to recover from disturbance (see Chapter 4), and the resulting increase in structure-associated fish species in the lagoon (see Chapter 5). Eelgrass is expected to persist in the lagoon, provided adequate depth and tidal flushing are maintained through regular maintenance dredging.

Fresh water continues to enter the lagoon system through multiple drainages located in the east basin, the largest of which is San Marcos Creek. This supports the freshwater and brackish marsh that have persisted in the eastern portion of the east basin. These habitats will likely expand and contract annually depending on volume and duration of freshwater flows. Freshwater and brackish marsh provide a notably different habitat structure than the adjacent salt marsh or uplands and are occupied by a different assemblage of bird species, including various rails, passerine species, and dabbling ducks in the open water areas in the freshwater marsh.

The limited distribution of non-native species is encouraging and likely the result of the continual saltwater influence that discourages most upland non-natives. Salt cedar and giant reed have not expanded and are not expected to spread much further in the future due to their limited distribution on the disturbed upland flanks of the lagoon. The stand of non-native eucalyptus on the north shore was regularly occupied by migrating warblers and was used as a rookery by several heron species and remains an asset to the lagoon environment.

Upland habitats did not change substantially following restoration, nor are they expected to in the future in relation to the physical and biological processes under way at the lagoon. The Diegan coastal sage scrub on the north shore supports the federally listed threatened coastal California gnatcatcher (*Polioptila californica californica*). This habitat improves the interface between the wetland habitats and the urban areas and provides some linkage for wildlife moving between lagoon and upland habitats.

In addition to the maturation of the vegetation communities, the increase in TOC seen at the high and middle marsh stations reflects the development of a nutrient pool in the sediment. Zedler (1996) noted that organic matter accumulates slowly in marsh systems. Prior to the restoration, much of the upper and middle marsh vegetation was subject to long periods of inundation and desiccation and was less vigorous than after tidal influence was restored. Although large algal mats formed seasonally in the lagoon pre-restoration, they were typically not coincident with the marginal marsh vegetation and therefore not a major source of sediment carbon in vegetated areas. Post-restoration, the marsh system is much more stable, with vegetation becoming denser over time, more strata of plant material, and likely more robust and extensive root systems. The additional size and complexity of the marsh structure provides a great detrital production source and enhances its ability to trap waterborne detritus. The marsh supports a film of microalgae over much of the surface of mudflat beneath the vegetation. These factors, in combination with an increase in infaunal invertebrate activities, has contributed to an increase in the carbon content of the soil at many of the high and middle marsh stations.

There was no clear pattern in the soil TOC over time at the low marsh transects, where most of the samples were collected from unvegetated or submerged mudflat. In the later monitoring years, cordgrass was present at some of the low marsh transects. The sample size, however, was too small to see any clear connections between vegetation presence and soil TOC levels. Overall, TOC was much lower at these transects than at the higher elevations. The low marsh transects experienced nearly daily tidal inundation and little to no detrital accumulation, though some macroalgae did become trapped in the cordgrass areas where it had become established.

3.4 RECOMMENDATIONS

The following actions are recommended with respect to the continued health and maintenance of the vegetation communities at Batiquitos Lagoon.

- The collection of aerial imagery every five years to track gross changes in vegetation communities that may occur in response to increased maintenance needs or major storm events.

- The introduction of select salt marsh species in order to increase habitat complexity and diversity, including a targeted introduction of salt marsh bird's-beak (*C. maritimus*) into the east end of the lagoon where localized conditions are highly appropriate for the species.

- The periodic surveillance for and eradication of invasive non-native species such as pampas grass, giant reed, salt cedar, and *Phragmites australis*.

- The eradication of the existing populations of *P. australis*, giant reed, and salt cedar to preclude potential spread and loss of the native coastal salt marsh community.

- Regular restoration and maintenance of tidal conditions to avoid highly fluctuating conditions of tidal muting through time.

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